WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the March 2013 issue of *CERN Courier*.

The LHC may be currently leading studies of particle physics at the high-energy frontier but the particle-physics community has for several years been looking hard at what machine should complement the LHC in future. The favoured option, a high-energy linear electron–positron collider, has been the focus of two international efforts that are now coming closer together. This month's lead feature reports on a meeting at the 2012 IEEE Nuclear Science Symposium, which provided the opportunity to discuss the technological developments on a broader stage. Meanwhile, after a successful period of proton–ion collisions, the LHC has entered its first long shutdown, which will see a huge effort in maintenance and consolidation.

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CERN COURIER

VOLUME 53 NUMBER 2 MARCH 2013

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Covering current developments in high-energy physics and related fields worldwide

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On the cover: After providing physicists with huge quantities of data, it is time for the LHC to get a facelift, which will involve the replacement of some cryomagnets (p26).

News

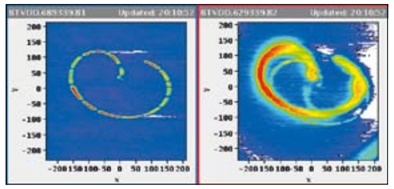
LHC News

Proton–ion collisions: the final challenge

In the last beam period before a two-year shutdown, the LHC began 2013 with a challenge: proton–ion collisions. Following a trial run in September (*CERN Courier* November 2012 p6), the machine went into full operation beyond its design specification, producing head-on collisions of protons with lead nuclei from mid-January to mid-February. At 5 TeV per colliding nucleon pair, the gain in collision energy is a factor of 25 above previous collisions of a similar type, making it one of the largest such gains in the history of particle accelerators.

Commissioning this new and almost unprecedented mode of collider operation was a major challenge for both the teams behind the LHC and its injector chain. The LHC configuration had to be modified quickly before and during the short run to achieve a number of physics goals.

Nonetheless, on 11 January, single bunches of protons and lead nuclei were injected into the LHC and successfully ramped to full energy. Over the following night the LHC-operations and beam-physics teams sprang into action to commission and measure the optics through a completely new sequence to squeeze the beams at collision. Interventions on the power and cryogenics systems slowed down the commissioning plan but by 20 January stable beams had been achieved with 13 bunches per beam.



During a beam dump, the complete bunch train is spread in a spiral pattern over the beam-dump material. The different patterns of the proton beam, left, and lead-nuclei beam, right, reflect the greater ionization energy loss of the lead nuclei in the beam-dump material.

In the next fill of the machine, the first bunch-trains were injected, leading to stable beams with 96 bunches of protons and 120 of ions. This important fill allowed the study of "moving", long-range beam–beam encounters. Stationary long-range encounters occur in proton–proton or lead–lead runs, when bunches in the two beams "see" one another as they travel in the same vacuum chamber on either side of the experiments. The situation becomes more complicated with proton–lead collisions because the long-range encounters move as a result of the different revolution times of the two species – a key feature of proton–lead operation.

At injection energy, lead ions travel more slowly than protons and complete eight fewer turns a minute round the LHC (674,721 turns compared with 674,729 turns for protons). As a result, the two beams – and their RF systems – run independently at different frequencies. Once the energy has been ramped up, the frequency differences become small enough for the RF systems to be locked together in a non-trivial process known as "cogging".

During the first cogging exercises, high beam-losses triggered beam dumps. This was later found to be caused by an improper synchronization of the two RF frequencies, and careful fine-tuning of the cogging process overcame the problem. After the cogging exercise and throughout the physics fill, the beams run "off-momentum" with opposite offsets to their orbits, requiring special corrections of the beam optics.

Every so often the source of the lead ions has to be replaced. A small sliver of solid isotopically pure ^{208}Pb is placed in a ceramic crucible that sits in an "oven" casing at the end of a metal rod. The metal is heated to around 800°C and ionized to become plasma. Ions are then extracted from the plasma and accelerated. Depending on the beam intensity, in stable running the accelerator chain consumes about 2 mg of lead every hour – a tiny amount, but 10 g costs some SwFr12,000 (approx US$13,000). In this image the position of the oven is being measured inside the source for Linac 3.

The full filling-scheme with 338 bunches in both beams was injected and successfully ramped on 21 January. In addition, the teams achieved a record lead-bunch intensity in the LHC thanks to the excellent performance of both the machine and the injectors. From 24 January onwards the machine was running routinely with stable beams of 338 bunches of protons in ring 1 (clockwise) and lead ions in ring 2. On 1 February, the beams were swapped so that ALICE, inherently an asymmetrical detector, could take data in both directions. A number of issues with cogging and squeezing made this beam reversal challenging, with the machine providing collisions between 192 ion bunches with 216 proton bunches for some days before the operators attempted to reach 338 bunches in each beam by the end of the run on 11 February.

Despite the short time-frame of this asymmetrical run, all seven LHC experiments were able to take data. On a good day, fills had peak luminosity at the beginning of the collisions of around $10^{29}\,s^{-1}\,cm^{-2}$ in ALICE, ATLAS and CMS. Integrated luminosity was well above expectations at around $2\,nb^{-1}$ a day for each of these experiments. This bodes well for the experimental analysis that will continue to go from strength to strength as the LHC enters its first long shutdown to consolidate and improve this impressive machine.

Sommaire en français

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News

LHC PHYSICS

ALICE and ATLAS find intriguing 'double ridge' in proton–lead collisions

In analysing data from last year's test run with proton–lead collisions in the LHC, the ALICE collaboration, followed almost immediately and independently by the ATLAS collaboration, have announced a surprising observation of a way that particles emerge from the high-energy collisions. Here the two collaborations report on their results.

To prepare for the recent LHC run with collisions of protons and lead ions, the LHC team performed a test run for a few hours last September. During this run the ALICE experiment recorded close to two million events, which have already led to new results (*CERN Courier*, December 2012 p6). Now, after an in-depth analysis, the ALICE collaboration has made the surprising observation of a double "ridge" structure in the correlation of particles emerging from the proton–lead collisions. This follows the observation by the CMS collaboration, using data from the same test run, of a "near-side" ridge-like correlation structure elongated in pseudorapidity – a measure of the angle an emerging particle takes relative to the direction of the beam (*CERN Courier* January/February 2013 p9).

The analysis performed by the ALICE collaboration characterizes two-particle angular correlations as a function of the event activity, which is quantified by the multiplicity, measured in a pair of forward scintillator detectors. The correlations are determined by counting the number of associated particles as a function of their difference in azimuth (Δϕ) and pseudorapidity (Δη) with respect to a trigger particle, in bins of this particle's transverse momentum $p_{T,trig}$ and associated transverse momentum $p_{T,assoc}$.

On the "near side" (Δϕ≈0), the separation of an Δη-elongated ridge structure from the contribution of a jet to the correlation is straightforward because the jet peak is concentrated around Δη = 0. It is more difficult on the "away side" (Δϕ≈π) because both structures are elongated in Δη and not easily separable by selecting on Δη. Experimentally, however, the near-side jet peak shows only a weak evolution with event multiplicity. So by subtracting the correlations at different event multiplicities from one another, it is possible to remove the jet-like contribution of the correlation to a large extent and to quantify modifications as a function of event multiplicity.

Figure 1 shows the two-particle correlation of low-multiplicity events subtracted from that of high-multiplicity events. It reveals a distinct excess in the correlation, which forms two ridges along Δη. The ridge on the near side, qualitatively similar to the one observed by CMS, is accompanied by a second ridge of similar magnitude on the away side, which is observed for the first time.

Such double-ridge structures are typically found in collisions of heavy ions and have their origins in collective phenomena occurring in the quark–gluon plasma that is created. However, these phenomena are not generally thought to occur in proton–lead collisions, where the size of the collision region is expected to be too small to allow the development of significant collective effects.

The projection of figure 1 onto Δϕ allows the yield and width of the near-side and away-side ridges to be quantified above a constant baseline. Figure 2 presents the ridge yield for different event multiplicities.

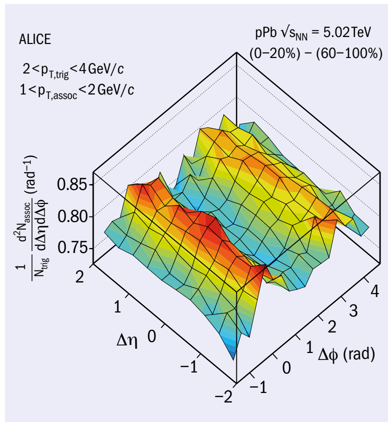


Fig. 1. Associated yield per trigger particle in Δϕ and Δη for pairs of charged particles with $2<p_{T,trig}<4$ GeV/c and $1<p_{T,assoc}<2$ GeV/c in proton–lead collisions in ALICE at $\sqrt{s_{NN}}$ = 5.02 TeV for the 0–20% multiplicity class, after subtraction of the associated yield obtained in the 60–100% event class.

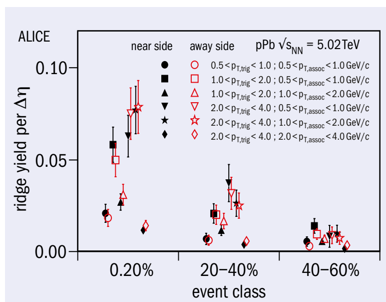


Fig. 2. Near-side (black closed symbols) and away-side (red open symbols) ridge yields per unit of Δη for different $p_{T,trig}$ and $p_{T,assoc}$ bins as a function of the multiplicity class. The error bars show statistical and systematic uncertainties added in quadrature. The points are slightly displaced horizontally for visibility.

It is remarkable that the near- and away-side yields always agree within uncertainties for a given sample despite the absolute values changing substantially with event multiplicity and p_T interval. Such a tight correlation between the yields suggests a common underlying physical origin for the two ridges. The extracted widths on the near side and the away side agree with each other within 20% and show no significant dependence on p_T, which suggests that the observed ridge is not of jet origin.

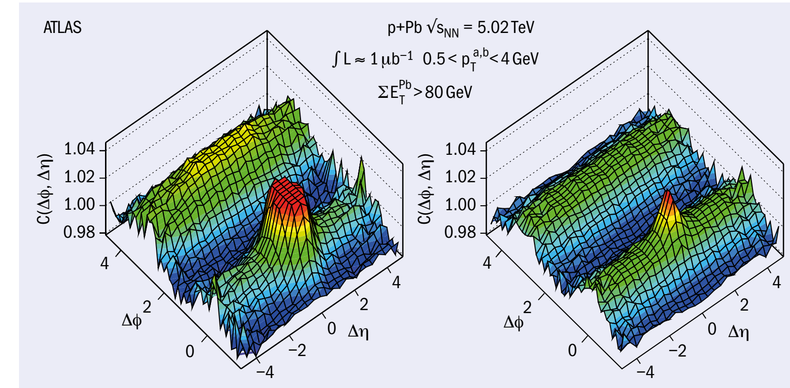
This intriguing and unexpected result still needs to be explained theoretically. Models that produce almost identical near- and away-side ridges are based on the colour-glass condensate framework or on hydrodynamical calculations that assume collective effects to occur also in proton–lead collisions. Whatever the origin may be, this observation has opened the window on a novel phenomenon. Further analysis of the high-statistics proton–lead data promises to yield exciting results.

Further reading
ALICE collaboration 2013 *Phys. Lett. B* **719** 29.

Studies of two-particle correlations in high-multiplicity proton–proton and proton–lead collisions at the LHC have shown a phenomenon frequently referred to as the "ridge". The ridge is a result of correlated production of particles at small relative-azimuthal angle (Δϕ) over a wide range of relative pseudorapidity (Δη). Using data from the highly successful pilot proton–lead run on 12 September 2012, ATLAS has shown that the ridge has an identical twin resulting from correlated production of particles that are back-to-back in azimuth.

To observe this twin, ATLAS had to remove background in the two-particle correlation function arising from hard scattering processes, momentum conservation and low-momentum resonance decays. Two-particle correlations were measured as a function of the proton–lead total transverse energy (ΣE_T) detected in one of the ATLAS forward calorimeters. The contribution of the background to the two-particle correlations was found to be independent of ΣE_T. As a result, the background could be measured in low-ΣE_T proton–lead collisions, which have little contribution from the ridge, and then subtracted from the two-particle correlation function in high-ΣE_T collisions.

The left and right panels in the figure (above) show the two-particle correlation function before and after background subtraction, respectively. Before subtraction, the correlation function includes: a jet peak near Δϕ = 0, Δη = 0; the previously observed ridge; and a broad structure arising from particles recoiling from the jet. The subtraction procedure removes the recoil contribution and nearly all of the jet peak, leaving behind two symmetrical ridges, extending over +/–5 units of Δη. The strength of the correlation increases with the transverse momentum of the particles over the measured p_T range, $0<p_T<6$ GeV.



The correlation function C(Δϕ,Δη) for two charged particles in proton–lead collisions having $\Sigma E_T > 80$ GeV before (left) and after (right) background subtraction.

The presence of such a symmetrical ridge had been predicted by QCD calculations invoking the colour-glass condensate, which describes the gluon content of a high-energy nucleus in the saturation regime. Alternative calculations that model the system formed in proton–lead collision as a "near perfect fluid" have also predicted a symmetrical ridge arising from final-state collective motion similar to that observed in lead–lead collisions. The data collected during the recent 2013 high-luminosity proton–lead run should provide a way to resolve this theoretical ambiguity. The good news is that either explanation will represent a ground-breaking advance in the understanding of high-energy proton–nucleus collisions.

Further reading
ATLAS collaboration 2012 arXiv:1212.5198 [hep-ex], submitted to *Phys. Rev. Lett.*

First measurements of electroweak boson fusion

In proton collisions at the LHC, vector boson fusion (VBF) happens when quarks from each one of the two colliding protons radiate W or Z bosons that subsequently interact or "fuse" as in the Feynman diagram shown on p8 where two W bosons fuse to produce a Z boson. Each quark radiating a weak boson exchanges four-momentum, Q^2, of around m_Z^2, m_W^2 in the t-channel. In this way, the two quarks scatter away from the beamline, typically inside the acceptance of the detector where they can be detected as hadronic jets. The distinctive signature of VBF is therefore the presence of two energetic hadronic jets (tagging jets), predominantly in the forward and backward directions with respect to the proton beamline.

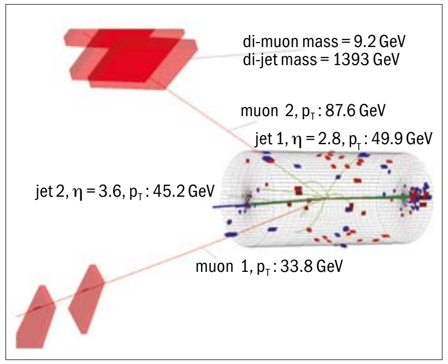
The study of VBF production of the Z boson is an important benchmark in establishing the presence of these processes in general and to cross-check measurements of Higgs VBF, where the radiated bosons fuse to form a Higgs boson. However, the VBF production of Z bosons has some intriguing differences with respect to that of Higgs bosons. In VBF Z-boson production, a large number of other purely electroweak non-VBF processes can lead to an identical final state and play an important role: they yield large negative interferences with the VBF production, which are related to the very foundations of the Standard Model. This situation makes VBF production of

Z bosons more complicated but also more interesting.

An additional and peculiar feature of VBF and all other purely electroweak processes is that no QCD colour is exchanged in the processes. This leads to the expectation of a "rapidity gap", or suppressed hadronic activity between the two tagging jets, which can also be identified in these events.

The CMS collaboration has searched for the pure electroweak production of a Z boson in association with two jets in the 7 TeV proton–proton collision data from 2011. They have analysed both dielectron and dimuon Z decays. The leptons are required to have transverse momenta $p_T > 20$ GeV/c and pseudorapidity $|\eta| < 2.4$; in addition, the dilepton invariant-mass is required to be consistent with that of the Z boson. The two associated tagging jets are reconstructed with two alternative algorithms ("particle flow" and "jet-plus-track") and are required to be within $|\eta| < 3.6$ and have $p_T > 65$ GeV/c (for the leading jet) and 40 GeV/c (subleading jet).

Selected events are passed to a multivariate boosted decision tree (BDT) that is trained to separate signal events from the large background stemming from the Z bosons produced via the Drell-Yan process and associated with two jets from additional QCD radiation. The BDT makes use of the full kinematic information of the three-body (Z+2jets) final state and of internal composition properties of the jet, which can discriminate if the jet originates from a gluon or a light quark. Figure 2a shows output distributions of the BDT for data and different simulated background components, as well as the simulated signal (purple) for selected dimuon Z decays. A fit to the BDT output distribution was used to measure the signal cross-section, σ(EWK Z+2jets) = 154 ± 24 (stat.) ± 46 (exp. syst.) ± 27 (th. syst.) ± 3 (lum.) fb. This is in good agreement with the theoretical expectation of 166 fb calculated at next-to-leading order precision.



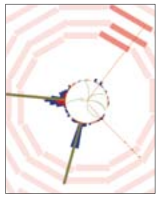


Fig. 1. Proton–proton collision recorded by CMS at √s = 7 TeV, featuring a dimuon system with the invariant mass of 90.2 GeV/c² and a forward- backward dijet system with the invariant mass of 1.4 TeV/c². Left: a 3D-view of the event. Right: an rφ-view reveals the transverse momentum balance of the dimuon and two-jet system.

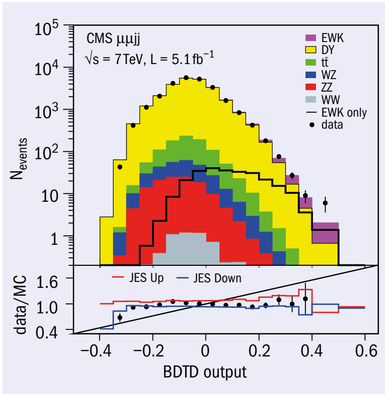


Fig. 2a. Left: Boosted decision tree output-distribution for selected Z+2jets events in the dimuon channel.

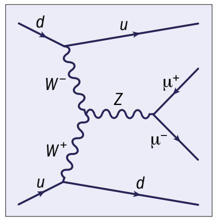


Fig. 2b. Right: Feynman diagram showing the production of a $\mu^+\mu^-jj$ final state in proton–proton collisions through vector boson fusion.

The hadronic activity in the rapidity interval between the two tagging jets and the radiation patterns of the selected Z boson events with two forward jets have also been measured and are in good agreement with the expectations.

● **Further reading**

CMS Public Analysis Summary *FSQ-12-019*. A paper is also being submitted to *JHEP*.

LHCb pins down X(3872) quantum numbers

One of the most interesting discoveries of the past decade is that of an unconventional hadron, the X(3872), by the Belle experiment (Belle 2003). Its decay to $J/\psi\pi^+\pi^-$ indicates that it is charmonium-like but its narrow width and mass above the threshold for decay to open charm do not fit any of the spectrum of predicted $c\bar{c}$ states. Several experiments have since confirmed this observation, in different production mechanisms and decay modes. In parallel to these experimental investigations, many theoretical interpretations have been put forward but the fundamental question remains open of whether the X(3872) is a quark–antiquark meson or a more exotic state.

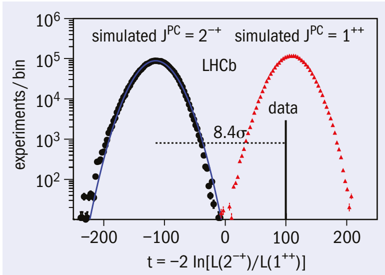


Fig. 1. Distribution of the test statistic for simulated experiments with $J^{PC} = 1^{++}$ (red) or 2^{-+} (blue), compared with the result from a data sample where the X(3872) is produced in B^+ decays. The fit clearly prefers $J^{PC} = 1^{++}$.

When any new resonance is observed it is mandatory to determine its quantum numbers. The observation of the decay $X(3872) \to J/\psi\gamma$ fixed the charge conjugation: C = +1. However, angular analyses left two possibilities for J^{PC}: 1^{++} and 2^{-+} (CDF 2007). Exotic models where the X(3872) is a DD^* molecule or a tetraquark state predict $J^{PC} = 1^{++}$.

The LHCb collaboration has now reported an analysis of the decay chain $B^+ \to X(3872)K^+ \to J/\psi\pi^+\pi^-K^+$, with $J/\psi \to \mu^+\mu^-$, where they use all five angular variables to maximize the separation power between the hypotheses of 1^{++} and 2^{-+}. The analysis uses the data sample of 1.0 fb⁻¹ that LHCb collected during 2011, which contains 313 ± 26 $B^+ \to X(3872)K^+$ decays. As figure 1 shows, the outcome of the multidimensional likelihood fit prefers $J^{PC} = 1^{++}$ with more than 8σ significance. Compared with previous analyses, the measurement benefits from larger statistics but importantly also makes use of the full angular information, which improves the ability to use correlations between angular variables to separate the two hypotheses (figure 2 shows an example).

This result rules out explanations of the X(3872) as the $\eta_{c2}(1^1D_2)$ state. Instead, it favours more exotic interpretations. However, distinguishing between molecular and tetraquark models will require studies of complementary decay modes. The 2.0 fb⁻¹ data sample that LHCb accumulated during 2012, as well as the larger samples that will be recorded in future LHC runs, will allow the collaboration to keep on the trail of these and other puzzles in heavy-flavour spectroscopy.

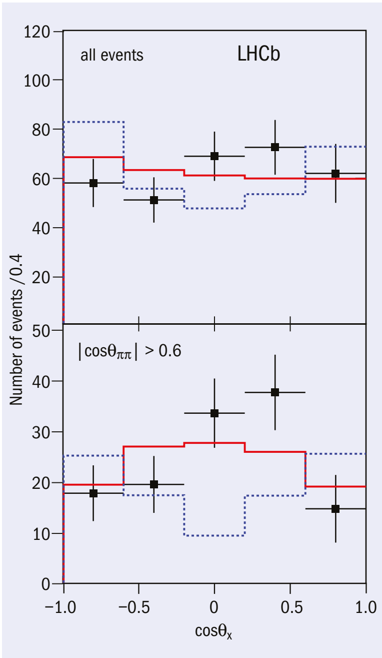


Fig. 2. Distribution of the cosine of the decay angle of the X(3872) for all candidates and for a subset with a selection on the cosine of the decay angle of the $\pi^+\pi^-$ system. The selected shows a clearer separation between the hypotheses, coloured as in figure 1.

● **Further reading**

Belle collaboration 2003 *Phys. Rev. Lett.* 91 262001.

CDF collaboration 2007 *Phys. Rev. Lett.* 98 132002.

LHCb collaboration 2013 LHCb-PAPER-2013–001, to be submitted to *Phys. Rev. Lett.*

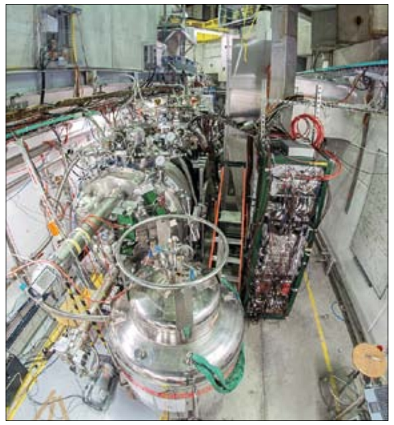
ANTIMATTER

AEgIS installation completed

Despite first being described over three centuries ago, gravity remains one of the least understood of the fundamental forces. At CERN's recently completed AEgIS experiment, a team is setting out to examine its effects on something much less familiar: antimatter.

Located in the experimental hall at the Antiproton Decelerator (AD), the AEgIS experiment is designed to make the first direct measurement of Earth's gravitational effect on antimatter. By sending a beam of antihydrogen atoms through very thin gratings, the experiment will be able to measure how far the antihydrogen atoms fall and in how much time – giving the AEgIS team a measurement of the gravitational coupling. The team finished putting all of the elements of the experiment together by the end of 2012, but they will have to wait for two years for beams to return to the AD hall following the Long Shutdown (LS1), which has just begun (p26).

To make progress in the meantime, the AEgIS team has decided to try out the experiment with hydrogen instead of antihydrogen. By replacing antiprotons with their own proton source, the team will be able to manufacture its own hydrogen beam to use for commissioning and testing the set-up. Surprisingly, carrying out the experiment with hydrogen will be more difficult technically than with antihydrogen. Another challenge will be in the production of the positronium that will be used in creating the hydrogen. The positronium needs to be moving fast enough to ensure that it does not decay before it meets the protons/antiprotons, but not so fast as to pass the protons/antiprotons altogether. The AEgIS team will be carrying out this commissioning during the coming months, opening up their set-up next month to make any necessary adjustments and to install a hydrogen detector and proton source.



The complete AEgIS set-up.

● For more, see *CERN Bulletin*: http://cds.cern.ch/journal/CERNBulletin/2013/06/News%20Articles/1496484?ln=en.

Sciencewatch

Compiled by John Swain, Northeastern University

Limits to growth in leaves and trees

Taller trees tend to have smaller leaves, and Kaare Jensen of Harvard University and Maciej Zwieniecki of the University of California in Davis think that they have worked out why. The reason seems to lie in the circulatory system of trees. Glucose is made in leaves by photosynthesis and despite leaves speeding up the process, it is possible that the stems, branches and trunk act as bottlenecks. At some point it is simply not worth growing larger leaves because the effect becomes more pronounced the taller the tree and the greater these bottlenecks.

Of course, leaves cannot be too small either, and detailed calculations based on data from 1925 species – with leaves from a few millimetres to more than a metre long – then constrain the maximum height of a tree to be about 100 m. The tallest California redwoods reach about 116 m.

Further reading

K H Jensen and M A Zwieniecki 2013 *Phys. Rev. Letts.* **110** 018104.

The Sequoia sempervivens of California are among the tallest trees in the world. (Image credit: Urasr/dreamstime.com.)

A reason for wrinkles

Hands always suffer from wrinkling when they stay in water too long but it seems that there is a good reason for it. Kyriacos Kareklas and colleagues of Newcastle University have found that while wrinkled fingers are no better at handling dry objects, they do function better with submerged objects.

Fingers could complete a task involving passing objects from one bin of water to another through a barrier with a small hole 12% faster after soaking for 30 minutes in water. This does makes some sense – after all, it is only hands and feet that wrinkle when soaked.

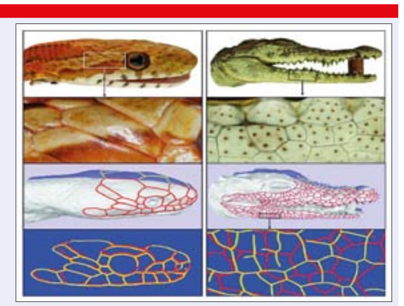
Further reading

K Kareklas *et al.* 2013 *Biology Letters* **9** 20120999.

Crocodile heads and the limits of genes

With all of the recent successes of genetics, it has become commonplace to think of biological patterns as arising from reaction-diffusion mechanisms controlled by genes. However, the crocodile has something to add to this.

Michael Milinkovitch of the University of Geneva and colleagues studied the patterns of crocodile-head scales and found that they are driven by physical processes. As crocodiles grow, their keratinized skin cracks in random ways, with no symmetry between one side of their head and the other – in contrast to what happens with the scales of snakes. So even a crocodile's genome has no say in how its scales will turn out. They will be distributed by physics with some randomness, rather than by information in genes.



Left: Head scales in most snakes are polygons (two upper panels), which overlap when reflected across the sagittal plane (bottom). Right: Polygonal head scales in crocodiles have a mainly random spatial distribution with no correspondence between left and right.

Further reading

M C Milinkovitch *et al* 2013 *Science* **339** 78.

Planck scale on a tabletop

As the LHC reaches ever higher energy, the Planck scale still seems a long way off – but there is reason for optimism. Jacob Bekenstein of the Hebrew University in Jerusalem has suggested a table-top experiment, just within the reach of present-day ultrahigh vacuum and cryogenic technology.

The idea is to couple a (quantum mechanical) single photon to a macroscopic piece of dielectric material by having it go through it, causing a tiny translation. No permanent impulse has to be imparted, with the translation inferred from detection of the photon and conservation of momentum. If the photon gets through, then the material must have moved by a Planck length. If space–time is rough on the Planck scale then this should show up as a change in the odds that a photon gets through. Amazingly, the numbers suggest that this could work.

Further reading

J D Bekenstein 2012 *Phys. Rev.* **D86** 124040.

Quantum dots from earthworms

Quantum dots – fluorescent nanocrystals – have a range of applications but they are not always easy to make. Now, Mark Green of King's College, London, and colleagues have found an environmentally friendly way of making biocompatible cadmium telluride (CdTe) quantum dots. They spiked the ground where earthworms (*Lumricus rubellus*) lived with cadmium chloride and sodium telluride. Eleven days later, they were able to recover green fluorescent CdTe quantum dots from the guts of the worms. As a bonus, the dots came out coated with a passivating layer that makes them water-soluble. In addition to being a fabrication technique, understanding the biology and biochemistry involved could help in heavy-metal remediation

Further reading

S R Stürzenbaum *et al.* 2012 *Nature Nanotechnology* **8** 57.

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Astrowatch

Compiled by Marc Türler, ISDC and Observatory of the University of Geneva

Pulsar exhibits puzzling switches in state

Astronomers have detected simultaneous X-ray and radio-mode switches in co-ordinated observations of a pulsar. Pulsed X-ray emission is only present in states of weak radio emission. This indicates a rapid global change in the magnetosphere, which challenges current emission theories.

Pulsars were discovered in 1967 as flickering sources of radio waves and were soon interpreted as being rotating, strongly magnetized neutron stars. The radiation is thought to be emitted by high-energy particles moving along the lines of magnetic field. As the emission is concentrated in two cones emerging from the magnetic poles, the source behaves like a lighthouse. We see a pulse each time that the radiation beam is pointed towards the Earth. This happens at the spin frequency of the neutron star because the rotation and magnetic axes are generally misaligned.

Among the thousands of known pulsars, only a small fraction has been detected in X-rays or gamma-rays (*CERN Courier* September 2006 p13, December 2008 p9). The X-ray emission can be steady or pulsed. The steady X-ray emission is high for young neutron stars and decreases as their surface temperature falls. The pulsed emission suggests that X-ray-emitting hot-spots are located at the magnetic poles.

Astronomers know of only a handful of old pulsars that shine in X-rays. One of them is PSR B0943+10, which is five million years old. This source also switches suddenly between a radio-bright and a radio-quiet state at intervals of several hours. It is therefore a prime target to investigate the X-ray behaviour associated with changes of the radio mode. This idea was suggested

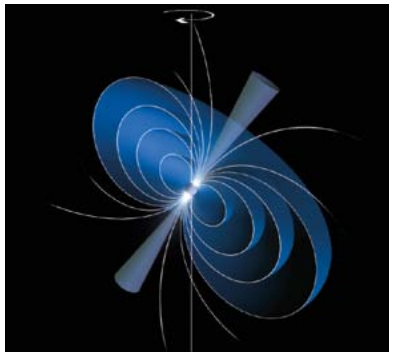


Illustration of a pulsar in a state with glowing X-ray emission at the magnetic poles and weak radio emission from the cones that stem from the poles. Pulsed emission results from the misalignment of the magnetic and rotational axes. (Image credit: ESA/ATG medialab.)

by a team led by Wim Hermsen of the Netherlands Institute for Space Research (SRON) and the Astronomical Institute "Anton Pannekoek" of the University of Amsterdam. It then took them five years to convince the time-allocation committee to schedule some long periods of observation with ESA's X-ray Multi-Mirror Mission (XMM-Newton) satellite co-ordinated with radio telescopes.

The satellite performed six observations of six hours each on PSR B0943+10 at the end of 2011. Radio-data were gathered at the same time by the Indian Giant Metrewave Radio Telescope (GMRT) and the international Low-Frequency Array (LOFAR) in the Netherlands. The result of the campaign was completely unexpected. The X-ray emission was found not to follow the states of radio brightness. On the contrary, it was observed to be weak when the source is bright in radio emission and vice versa.

The timing and spectral analysis of the XMM-Newton data offered yet more surprises. The source was found to pulsate in X-rays only during the X-ray-bright phase corresponding to the quiet-radio state. During this phase, the X-ray emission appears to be the sum of two components: a pulsating component consisting of thermal X-rays, which is seen to switch off during the X-ray-quiet phase; and a persistent one consisting of non-thermal X-rays.

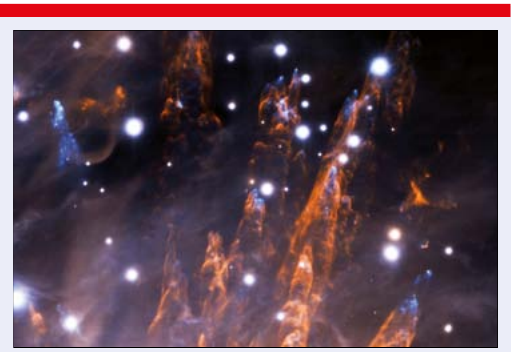
The results suggest that the entire magnetosphere around the pulsar is switching from one state to another within a few seconds. The rapidity of this change is puzzling but it is not the only issue. The observed radio and X-ray behaviour is predicted by neither of the leading models for pulsar emission.

Hermsen and his team plan to repeat the same study for another pulsar that has similar radio properties but with a different geometrical configuration. This will allow them to test whether the viewing angle with respect to the magnetic and rotational axes has an effect on the properties of the X-ray emission. In the meantime, theorists will be busy investigating possible physical mechanisms that could cause the observed sudden and drastic changes to the pulsar's magnetosphere.

● **Further reading**
W Hermsen *et al.* 2013 *Science* **339** 436.

Picture of the month

This extraordinary image taken by the Gemini South 8.2-m telescope depicts hot bullets of gas tracing their way through the Orion Nebula (*CERN Courier* March 2011 p10). The Orion Bullets have been ejected from the Trapezium cluster of bright, young stars at the heart of the star-forming region. In this false-colour infrared view, the blue bullets are clumps of hot gas (around 5000 K) with a size of about 10 times Pluto's orbit. Travelling with a speed of about 400 km/s they leave behind the orange cone-shaped wakes of shock-heated gas. The unprecedented image resolution (around 0.1 arcsec) illustrates the power of the new GeMS adaptive optics system. Five lasers are used to create artificial guide-stars to measure and correct atmospheric turbulence in real time (*CERN Courier* November 2012 p15). (Image credit: Gemini Observatory/AURA.)



CERN Courier Archive: 1970

A look back to CERN Courier vol. 8, March 1970, compiled by Peggie Rimmer

Berkeley

Important experiment on the cheap

On 5 December 1969 the University of Chicago-Berkeley neutrino neutral current experiment concluded its run at the 6 GeV Bevatron. The experimenters looked for the reaction $K^+ \to \pi^+ + \nu + \bar{\nu}$ which, had it been observed, would have been evidence of the existence of such currents. During the course of the experiment a total of 1.5×10^9 positive kaons decayed within the detecting apparatus but no example of the neutral current reaction was observed.

Preliminary analysis of the data indicates that the branching ratio for K^+ decay in this manner is less than 1.2×10^{-6}. The experiment is important because the absence of this decay mode (and of the related mode $K^+ \to \pi^+ + e^+ + e^-$) is an unsolved puzzle in weak interaction theory. One possible interpretation of this observation is that electrons and neutrinos carry a quantum number which forbids the creation of isolated electron or neutrino pairs by weak interactions.

Left to right: R Hildebrand, R Stiening and J Klems, the physicists who have carried out the neutrino neutral-current experiment at Berkeley. The entire detection apparatus, which is unusually simple and compact for a high-energy physics experiment, is shown behind them. (Image credit: LRL.)

An unusual feature of the experiment is that the apparatus was put together almost entirely from "odds and ends". One crucial part consisted of two 15-year-old oscilloscopes, used to display the $\pi^+ \to \mu^+ \to e^+$ decay sequence. No computers, either online or off-line, were used in the reduction of the data.

● Compiled from texts on p87.

CERN News

Computer takes over

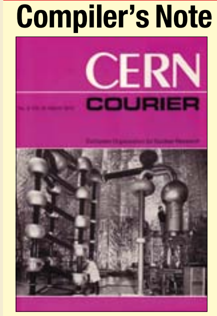
On 29 January, a rather unusual test was made during one of the machine development periods on the CERN proton synchrotron.

All of the dipolar corrections guiding the beam in the horizontal plane were switched off and it was impossible to accelerate the beam to full energy. The beam would make only thirty revolutions in the machine (lasting about 200 μs). The IBM 1800 machine control computer was then asked to bring the beam back on. After successive optimization procedures, the computer succeeded in accelerating a beam with an intensity of 96×10^{10} protons per pulse. The intensity before beginning the tests had been about 80×10^{10} protons per pulse.

The test was part of the research programme of the controls group concerning the use of online computers in accelerator control. Though the experiment does not foreshadow computer-controlled operation in the near future, it does show how the use of computers can help in accelerator control. This is believed to be the first time that the intensity of an accelerator in use for physics has been optimized by computer.

● Compiled from texts on p84.

Compiler's Note



The K^+ is an up quark plus antistrange quark; the π^+ is an up quark plus an antidown quark. Thus the decay $K^+ \to \pi^+ + \nu + \bar{\nu}$ violates flavour conservation and is forbidden in any first-order Standard Model process. However, it can proceed via a flavour-changing, second-order weak interaction, involving two force carrier bosons and other quarks. This ultrarare decay, sensitive to effects predicted in extensions to the Standard Model, is one of the most challenging interactions in particle physics.

In 1995, a quarter of a century after the null result reported here, experiment E787 at the Brookhaven National Laboratory made the first sighting of the decay. A second event appeared in 1998 and by 2008 a total of seven events had been observed by E787 and its successor E949 – statistics that could only provide limitations on possible physics beyond the Standard Model.

Now, experiment NA62 at CERN is preparing to measure the branching ratio of this decay with a precision of 10%, similar to that of current Standard Model predictions. Data-taking is planned to start in the North Area at the SPS in 2014, with the aim of collecting some 100 events within two years.

Physicists are nothing if not patient.

Feeding the PS with nitrogen

Following successful tests carried out on sector 4 of the PS vacuum chamber, it has been decided to use dry nitrogen, before atmospheric air, to fill the vacuum chambers when the vacuum has to be broken for maintenance or modification of equipment. This trick, which is already in use in other laboratories and by certain CERN groups, has the advantage of shortening pumping time by a factor of more than three when the high vacuum has to be re-established.

The reduction in pumping time is due to absorption of dry nitrogen by the chamber walls, which inhibits the subsequent absorption of water vapour when atmospheric air is allowed in. This is of special importance since the PS oil diffusion pumps are at present being replaced by ion pumps, which are particularly sensitive to moisture.

● Compiled from texts on p86.

Linear-collider technologies for all

A special event at the 2012 IEEE Nuclear Science Symposium provided a broader stage to discuss technological developments for a future linear collider.

A superconducting RF accelerator structure made from the purest niobium, together with a disc of a CLIC accelerating structure prototype. (Image credit: DESY.)

The LHC at CERN is a prime example of worldwide collaboration to build a large instrument and pursue frontier science. The discovery there of a particle consistent with the long-sought Higgs boson points to future directions both for the LHC and more broadly for particle physics. Now, the international community is considering machines to complement the LHC and further advance particle physics, including the favoured option: an electron–positron linear collider (LC). Two major global efforts are underway: the International Linear Collider (ILC), which is distributed among many laboratories; and the Compact Linear Collider (CLIC), centred at CERN. Both would collide electrons and positrons at tera-electron-volt energies but have different technologies, energy ranges and timescales. Now, the two efforts are coming closer together and forming a worldwide linear-collider community in the areas of accelerators, detectors and resources.

Last year, the organizers of the 2012 IEEE Nuclear Science Symposium held in Anaheim, California, decided to arrange a Special Linear Collider Event to summarize the accelerator and detector concepts for the ILC and CLIC. Held on 29–30 October, the event also included presentations on the impact of LC technologies for different applications and a discussion forum on LC perspectives. It brought together academic, industry and laboratory-based experts, providing an opportunity to discuss LC progress with the accelerator and instrumentation community at large, and to justify the investments in technology required for future particle accelerators and detectors. Representatives of the US Funding Agencies were also invited to attend.

CERN's director-general, Rolf Heuer, introduced the event before Steinar Stapnes, CLIC project leader, and Barry Barish, director of the ILC's Global Design Effort (GDE), reviewed the two projects. The ILC concept is based on superconducting radio-frequency (SRF) cavities, with a nominal accelerating field of 31.5 MV/m, to provide e^+e^- collisions at sub-tera-electron-volt energies in the centre-of-mass. The CLIC studies focus on an option for a multi-tera-electron-volt machine using a novel two-beam acceleration scheme, with normal-conducting accelerating structures operating at fields as high as 100 MV/m. In this approach, two beams run parallel to each other: the main beam, to be accelerated; and a drive beam, to provide the RF power for the accelerating structures.

Both studies have reached important milestones. The *CLIC Conceptual Design Report* was released in 2012, with three volumes for physics, detectors and accelerators. The project's goals for the coming years are well defined, the key challenges being related to system specifications and performance studies for accelerator parts and detectors, technology developments with industry and implementation studies. The aim is to present an implementation plan by 2016, when LHC results at full design energy should become available.

The ILC GDE took a major step towards the final technical design when a draft of the four-volume *Technical Design Report* (TDR) was presented to the ILC Steering Committee on 15 December 2012 in Tokyo. This describes the successful establishment of ▷

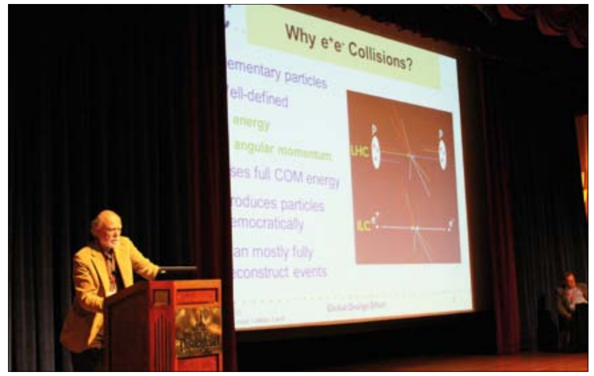
Accelerators

the key ILC technologies, as well as advances in the detector R&D and physics studies. Although not released by the time of the NSS meeting, the TDR results served as the basis for the presentations at the special event. The chosen technologies – including SRF cavities with high gradients and state-of-the-art detector concepts – have reached a stage where, should governments decide in favour and a site be chosen, ILC construction could start almost immediately. The ILC TDR, which describes a cost-effective and mature design for an LC in the energy range 200–500 GeV, with a possible upgrade to 1 TeV, is the final deliverable for the GDE mandate.

The newly established Linear Collider Collaboration (LCC), with Lyn Evans as director, will carry out the next steps to integrate the ILC and CLIC efforts under one governance. One highlight in Anaheim was a talk on the physics of the LC by Hitoshi Murayama of the Kavli Institute for Mathematics and Physics of the Universe (IPMU) and future deputy-director for the LCC. He addressed the broader IEEE audience, reviewing how a "Higgs factory" (a 250 GeV machine) as the first phase of the ILC could elucidate the nature of the Higgs particle – complementary to the LHC. The power of the LC lies in its flexibility. It can be tuned to well defined initial states, allowing model-independent measurements from the Higgs threshold to multi-tera-electron-volt energies, as well as precision studies that could reveal new physics at a higher energy scale.

Detailed technical reviews of the ILC and CLIC accelerator concepts and associated technologies followed the opening session. Nick Walker of DESY presented the benefits of using SRF acceleration with a focus on the "globalization" of the technology and the preparation for a worldwide industrial base for the ILC construction. The ultralow cavity-wall losses allow the use of long RF pulses, greatly simplifying the RF source while facilitating efficient acceleration of high-current beams. In addition, the low RF frequency (1.3 GHz) significantly reduces the impedance of the cavities, leading to reduced beam-dynamics effects and relatively relaxed alignment tolerances. More than two decades of R&D have led to a six-fold increase in the available voltage gradient, which – together with integration into a single cryostat (cryomodule) – has resulted in an affordable and mature technology. One of the most important goals of the GDE was to demonstrate that the SRF cavities can be reliably produced in industry. By the end of 2012, two ambitious goals were achieved: to produce cavities qualified at 35 MV/m and to demonstrate that an average gradient of 31.5 MV/m can be reached for ILC cryomodules. These high-gradient cavities have now been produced by industry with 90% yield, acceptable for ILC mass-production.

CERN's Daniel Schulte reviewed progress with the CLIC concept, which is based on 12 GHz normal conducting accelerating structures and a two-beam scheme (rather than klystrons) for a cost-effective machine. The study has over the past two decades developed high-gradient, micron-precision accelerating structures that now reach more than 100 MV/m, with a breakdown probability of only $3\times10^{-7}\,\mathrm{m}^{-1}\,\mathrm{pulse}^{-1}$ during high-power tests and more than 145 MV/m in two-beam acceleration tests at the CTF3 facility at CERN (tolerating higher breakdown rates). The CLIC design is compatible with energy-staging from the ILC baseline design of 0.5 TeV up to 3 TeV. The ILC and CLIC studies are collaborating



Barry Barish, who has led the ILC GDE to the delivery of the draft TDR. (Image credit: ILC GDE.)

closely on a number of technical R&D issues: beam delivery and final-focus systems, beam dynamics and simulations, positron generation, damping rings and civil engineering.

Another area of common effort is the development of novel detector technologies. The ILC and CLIC physics programmes are both based on two complementary detectors with a "push–pull concept" to share the beam time between them. Hitoshi Yamamoto of Tohoku University reviewed the overall detector concepts and engineering challenges: multipurpose detectors for high-precision vertex and main tracking; a highly granular calorimeter inside a large solenoid; and power pulsing of electronics. The two ILC detector concepts (ILD and SiD) formed an excellent starting point for the CLIC studies. They were adapted for the higher-energy CLIC beams and ultra-short (0.5 ns) bunch-spacing by using calorimeters with denser absorbers, modified vertex and forward detector geometries, and precise (a few nanosecond) time-stamping to cope with increased beam-induced background.

Vertex detectors, a key element of the LC physics programme, were presented by Marc Winter of CNRS/IPHC Strasbourg. Their requirements address material budget, granularity and power consumption by calling for new pixel technologies. CCDs with 50 μm final pixels, CMOS pixel sensors (MIMOSA) and depleted field-effect transistor (DEPFET) devices have been developed successfully for many years and are suited to running conditions at the ILC. For CLIC, where much faster read-out is mandatory, the R&D concentrates on multilayer devices, such as vertically integrated 3D sensors comprising interconnected layers thinner than 10 μm, which allow a thin charge-sensitive layer to be combined with several tiers of read-out fabricated in different CMOS processes.

Both ILD and SiD require efficient tracking and highly granular calorimeters, optimized for particle-flow event reconstruction but differ in the central-tracking approach. ILD aims for a large time-projection chamber (TPC) in a 3.5–4 T field, while SiD is designed as a compact, all-silicon tracking detector with a 5 T solenoid. Tim Nelson of SLAC described tracking in the SiD concept with particular emphasis on power, cooling and minimization of material. Takeshi Matsuda of KEK presented progress on the low material-budget field cage for the TPC and end-plates based on micropattern gas detectors (GEMs, Micromegas or InGrid).

Apart from their dimensions, the electromagnetic calorimeters are similar for the ILC and CLIC concepts, as Jean-Claude Brient of Laboratoire Leprince-Ringuet explained. The ILD and the SiD detectors both rely on the silicon-tungsten sampling calorimeters, with emphasis on the separation of close electromagnetic showers. The use of small scintillator strips with silicon photodiodes operated in Geiger mode (SiPM) read-out as an active medium is being considered, as well as mixed designs using alternating layers of silicon and scintillator. José Repond of Argonne National Laboratory described the progress in hadron calorimetry, which is optimized to provide the best possible separation of energy deposits from neutral and charged hadrons. Two main options are under study: small plastic scintillator tiles with embedded SiPMs or higher granularity calorimeters based on gaseous detectors. Simon Kulis of AGH-UST Cracow addressed the importance of precise luminosity measurement at the LC and the challenges of the forward calorimetry.

In the accelerator instrumentation domain, tolerances at CLIC are much tighter because of the higher gradients. Thibaut Lefevre of CERN, Andrea Jeremie of LAPP/CNRS and Daniel Schulte of CERN all discussed beam instrumentation, alignment and module control, including stabilization. Emittance preservation during beam generation, acceleration and focusing are key feasibility issues for achieving high luminosity for CLIC. Extremely small beam sizes of 40 nm (1 nm) in the horizontal (vertical) planes at the interaction point require beam-based alignment down to a few micrometres over several hundred metres and stabilization of the quadrupoles along the linac to nanometres, about an order of magnitude lower than ground vibrations.

Two sessions were specially organized to discuss potential spin-off from LC detector and accelerator technologies. Marcel Demarteau of Argonne National Laboratory summarized a study report, *ILC Detector R&D: Its Impact*, which points to the value of sustained support for basic R&D for instrumentation. LC detector R&D has already had an impact in particle physics. For example, the DEPFET technology is chosen as a baseline for the Belle-II vertex detector; an adapted version of the MIMOSA CMOS sensor provides the baseline architecture for the upgrade of the inner tracker in ALICE at the LHC; and construction of the TPC for the T2K experiment has benefited from the ILC TPC R&D programme.

The LC hadron calorimetry collaboration (CALICE) has initiated the large-scale use of SiPMs to read out scintillator stacks (8000 channels) and the medical field has already recognized the potential of these powerful imaging calorimeters for proton computed tomography. Erika Garutti of Hamburg University described another medical imaging technique that could benefit from SiPM technology – positron-emission tomography (PET) assisted by time-of-flight (TOF) measurement, with a coincidence-time resolution of about 300 ps FWHM, which is a factor of two better than devices available commercially. Christophe de La Taille of CNRS presented a number of LC detector applications for volcano studies, astrophysics, nuclear physics and medical imaging.

Accelerator R&D is vital for particle physics. A future LC accelerator would use high-technology coupled to nanoscale precision and control on an industrial scale. Marc Ross of SLAC introduced the session, "LC Accelerator Technologies for Industrial Applications",

The IEEE tradition

The 2012 Institute of Electrical and Electronics Engineers (IEEE) Nuclear Science Symposium (NSS) and Medical Imaging Conference (MIC) together with the Workshop on Room-Temperature Semiconductor X-Ray and Gamma-Ray Detectors took place at the Disneyland Hotel, Anaheim, California, on 29 October – 3 November. Having received over 850 NSS abstracts – a record number of NSS submissions for the conferences in North America – the 2012 IEEE NSS/MIC Symposium attracted more than 2200 attendees. The NSS series, which started in 1954, offers an outstanding opportunity for detector physicists and other scientists and engineers interested in the fields of nuclear science, radiation detection, accelerators, high-energy physics, astrophysics and related software. During the past decade the symposium has become the largest annual event in the area of nuclear and particle-physics instrumentation, providing an international forum to discuss the science and technology of large-scale experimental facilities at the frontiers of research.

with an institutional perspective on the future opportunities of LC technologies. The decision in 2004 to develop the ILC based on SRF cavities allowed an unprecedented degree of global focus and participation and a high level of investment, extending the frontiers of this "technology" in terms of performance, reliability and cost.

Particle accelerators are widely used as tools in the service of science with an ever growing number of applications to society. An overview of industrial, medical and security-related uses for accelerators was presented by Stuart Henderson of Fermilab. A variety of industrial applications makes use of low-energy beams of electrons, protons and ions (about 20,000 instruments) and some 9000 medical accelerators are in operation in the world. One example of how to improve co-ordination between basic and applied accelerator science is the creation of the Illinois Accelerator Research Centre (IARC). This partnership between the US Department of Energy and the State of Illinois aims to unite industry, universities and Fermilab to advance applications that are directly relevant to society.

SRF technology has potential in a number of industrial applications, as Antony Favale of Advanced Energy Systems explained. For example, large, high-power systems could benefit significantly using SRF, although the costs of cavities and associated cryomodules are higher than for room-temperature linacs; continuous-wave accelerators operating at reasonably high gradients benefit economically and structurally from SRF technology. The industrial markets for SRF accelerators exist for defence, isotope production and accelerator-driven systems for energy production and nuclear-waste mitigation. Walter Wuensch of CERN described how the development of normal-conducting linacs based on the high-gradient 100 MV/m CLIC accelerating structures may be beneficial for a number of accelerator applications, from X-ray free-electron lasers to industrial and medical linacs. Increased performance of high-gradient accelerating structures, translated into lower cost, potentially broadens the market for such accelerators. In addition, industrial applications increasingly require micron-precision 3D geometries, similar to the CLIC prototype accelerating structures. A number ▷

of firms have taken steps to extend their capabilities in this area, working closely with the accelerator community.

Steve Lenci of Communications and Power Industries LLC presented an overview of RF technology that supports linear colliders, such as klystrons and power couplers, and discussed the use of similar technologies elsewhere in research and industry. Marc Ross summarized applications of LC instrumentation, used for beam measurements, component monitoring and control and RF feedback.

The Advanced Accelerator Association Promoting Science & Technology (AAA) aims to facilitate industry-government-academia collaboration and to promote and seek industrial applications of advanced technologies derived from R&D on accelerators, with the ILC as a model case. Founded in Japan in 2008, its membership has grown to comprise 90 companies and 38 academic institutions. As the secretary-general Masanori Matsuoka explained, one of the main goals is a study on how to reach a consensus to implement the ILC in Japan and to inform the public of the significance of advanced accelerators and ILC science through social, political and educational events.

The Special Linear Collider Event ended with a forum that brought together directors of the high-energy-physics laboratories and leading experts in LC technologies, from both the academic research sector and industry. A panel discussion, moderated by Brian Foster of the University of Hamburg/DESY, included Rolf Heuer (CERN), Joachim Mnich (DESY), Atsuto Suzuki (KEK), Stuart Henderson (Fermilab), Hitoshi Murayama (IPMU), Steinar Stapnes (CERN) and Akira Yamamoto (KEK) .

The ILC has received considerable recent attention from the Japanese government. The round-table discussion therefore began with Suzuki's presentation of the discovery of a Higgs-like particle at CERN and the emerging initiative toward hosting an ILC in Japan. The formal government statement, which is expected within the next few years, will provide the opportunity for the early implementation of an ILC and the recent discovery at CERN is strong motivation for a staged approach. This would begin with a 250 GeV machine (a "Higgs factory"), with the possibility of increasing in energy in a longer term. Suzuki also presented the Japan Policy Council's recommendation, *Creation of Global Cities by hosting the ILC*, which was published in July 2012.

The discussion then focused on three major issues: the ILC Project Implementation Plan; the ILC Technology Roadmap; and the ILC Added Value to Society. While the possibility of implementing CLIC as a project at CERN to follow the LHC was also on the table, there was less urgency for discussion because the ILC effort counts on an earlier start date. The panellists exchanged many views and opinions with the audience on how the ILC international programme could be financed and how regional priorities could be integrated into a consistent worldwide strategy for the LC. Combining extensive host-lab-based expertise together with resources from individual institutes around the world is a mandatory first step for LC construction, which will also require the development of links between projects, institutions, universities and industry in an ongoing and multifaceted approach.

SRF systems – the central technology for the ILC – have many applications, so a worldwide plan for distributing the mass production of the SRF components is necessary, with technology-

Fig. 3. The discussion forum during the "Special LC Event" with, from left to right, Akira Yamamoto, Steinar Stapnes, Hitoshi Murayama, Stuart Henderson, Joachim Mnich, Atsuto Suzuki, Rolf Heuer and Brian Foster. (Image credit: IEEE.)

transfer proceeding in parallel, in partnership with funding agencies. Another issue discussed related to the model of global collaboration between host/hub-laboratories and industry to build the ILC, where each country shares the costs and human resources. Finally, accelerator and detector developments for the LC have already penetrated many areas of science. The question is how to improve further the transfer of technology from laboratories, so as to develop viable, on-going businesses that serve as a general benefit to society; as in the successful examples, such the IARC facility and the PET-TOF detector, presented in Anaheim.

Last, but not least, this technology-oriented symposium would have been impossible without the tireless efforts of the "Special LC Event" programme committee: Jim Brau, University of Oregon, Juan Fuster (IFIC Valencia), Ingrid-Maria Gregor (DESY Hamburg), Michael Harrison (BNL), Marc Ross (FNAL), Steinar Stapnes (CERN), Maxim Titov (CEA Saclay), Nick Walker (DESY Hamburg), Akira Yamamoto (KEK) and Hitoshi Yamamoto (Tohoku University). In all, this event was considered a real success. More than 90% of participants who answered the conference questionnaire rated it extremely important.

● Further reading

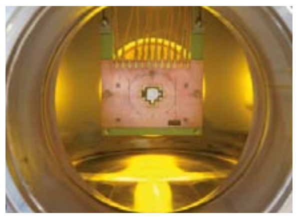
For all of the presentations, see http://www.desy.de/~nss2012/2012LCevent.html.

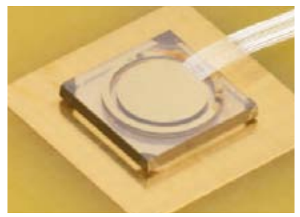
Résumé

Technologies du collisionneur linéaire

Le colloque 2012 de l'IEEE sur la science nucléaire avait à son programme une série spéciale consacrée au collisionneur linéaire, destinée à faire le point sur les concepts d'accélérateur et de détecteur pour les études relatives au Collisionneur linéaire international et au CLIC. Cela a aussi été l'occasion de présentations sur l'impact des technologies de collisionneur linéaire dans différentes applications ainsi que d'un forum de discussion sur les perspectives. Le colloque a rassemblé des spécialistes venant de différents horizons, universitaires, industriels et chercheurs en laboratoire, et a été l'occasion d'examiner de façon plus large la situation s'agissant des projets de collisionneur linéaire, et de justifier les investissements technologiques requis pour les futurs accélérateurs et détecteurs

Maxim Titov, CEA Saclay, Irfu, 2012 IEEE NSS programme chair.






Participants outside the Academic Building, with its famous bronze sphere in the foreground. (Image credit: Sarah LaPointe.)

Charm and beauty in Utrecht

Heavy flavours were the focus of an international workshop held last November.

The historic academic building of Utrecht University provided the setting for the 5th International Workshop on Heavy Quark Production in Heavy-Ion Collisions, offering a unique atmosphere for a lively discussion and interpretation of the current measurements on open and hidden heavy flavour in high-energy heavy-ion collisions. Held on 14–17 November, the workshop attracted some 70 researchers from around the world, a third of the participants being theorists and more than 20% female researchers. The topics for discussion covered recent results, upgrades and future experiments at CERN's LHC, Brookhaven's Relativistic Heavy-Ion Collider (RHIC) and the Facility for Antiproton and Ion Research (FAIR) at Darmstadt, as well as theoretical developments. There was a particular focus on the exchange of information and ideas between the experiments on open heavy-flavour reconstruction.

Open and hidden heavy flavour

Representatives from all of the major collaborations nicely summarized recent experimental results and prospects for future measurements. In particular, with the advent of the LHC, an unprecedented wealth of data on the production of heavy quarks and quarkonium in nuclear collisions has become available. One of the more spectacular effects observed at RHIC is the quenching of the transverse momentum (p_T) spectra of light hadrons, related to the energy loss of quarks inside the hot quark–gluon plasma (QGP) phase produced in lead–lead (PbPb) collisions. This has now been studied in detail for the first time by the ALICE, ATLAS and CMS collaborations in the heavy-quark sector.

Among the highlights presented at the workshop, the ALICE collaboration reported a strong suppression (up to a factor around 5) of the production of D mesons in PbPb collisions at a centre-of-mass energy, $\sqrt{s_{NN}}$, of 2.76 TeV, compared with proton–proton data at the same energy. The CMS experiment has also found a sizeable suppression of the yield of J/ψs coming from the decay of B hadrons. When this effect is compared with the one measured by the same experiments for light hadrons, interesting hints of a hierarchy of suppression are seen, with the beauty hadrons being less suppressed than the charmed hadrons and the latter less suppressed than light hadrons. Such an observation may be connected to the so called dead-cone effect, a reduction of small-angle gluon radiation for heavy compared with light quarks, predicted by QCD and related to the energy density reached in the medium.

In the quarkonium sector, the ALICE and CMS collaborations showed new and intriguing results on J/ψ and Υ production, respectively. A suppression of charmonium states had been previously observed at CERN's Super Proton Synchrotron (SPS) and at RHIC and was explained as an effect of the screening of the binding colour force in a QGP. With data from the LHC, accurate results ▷

on the bottomonium states have proved for the first time – beyond any doubt – that the less-strongly bound $\Upsilon(2S)$ and $\Upsilon(3S)$ are up to five times more strongly suppressed in a QGP with respect to the tightly bound $\Upsilon(1S)$ state, an observation that is expected in a colour-screening scenario. On the contrary, the ALICE collaboration sees a smaller suppression-effect for the J/ψ with respect to RHIC and the SPS, despite the larger energy density reached in nuclear collisions at the LHC. An interesting hypothesis relates this observation to a recombination of $c\bar{c}$ pairs, which are produced with high multiplicity in each PbPb collision, in the later stages when the system cools down and crosses the transition temperature between the QGP and the ordinary hadronic world.

Theoretical developments

The talks on theory provided quite a comprehensive overview of the vigorous research efforts towards a theoretical understanding of heavy-quark probes in heavy-ion collisions. The experimental findings on open heavy-flavour suppression and elliptic flow have led to many theoretical investigations of heavy-quark diffusion in the strongly coupled QGP. Most models use a relativistic Fokker-Planck-Langevin approach, with drag and diffusion coefficients taken from various microscopic models for the heavy-quark interactions with the hot and dense medium. The microscopic models include estimates from perturbative QCD for elastic- and/or radiative-scattering processes, T-matrix calculations using in-medium lattice potentials (from both the free and the internal thermodynamic potentials) and collision terms in full transport simulations, including $2 \leftrightarrow 2$ and $2 \leftrightarrow 3$ processes in perturbative QCD.

First studies of the influence of the hadronic phase on the modifications of the open-heavy-flavour medium were presented at the workshop. Estimates of the viscosity to entropy-density ratio, η/s, from the corresponding partonic and hadronic heavy-quark transport coefficients, lead to values that are not too far from the conjectured anti-de Sitter/conformal field theory lower bound of $1/4\pi$ in the phase-transition region, showing the characteristic minimum around the critical temperature, T_c. Results from a direct calculation of the heavy-quark transport coefficients via the maximum-entropy method applied to lattice-QCD correlation functions were also reported.

In the field of heavy quarkonia, the notion of a possible regeneration of heavy quarkonia via $q\bar{q}$ recombination in the medium in addition to the dissociation/melting processes leading to their suppression in the QGP has in recent years led to detailed studies on the bound-state properties of heavy quarkonia in the hot medium. Here, the models range from the evaluation of static $q\bar{q}$ potentials in hard-thermal-loop resummed thermal-QCD to a generalization of systematic nonrelativistic QCD and heavy-quark effective theory studies, generalizing from the vacuum to thermal field theory.

These theoretical studies have already led to major progress in understanding the possible microscopic mechanisms behind the coupling of heavy-quark degrees of freedom with the hot and dense medium created in heavy-ion collisions. In future, it might be possible to gain an even better quantitative understanding of fundamental quantities such as the transport coefficients of the QGP (for example η/s) and the dissociation temperatures of heavy quarkonia, which could provide a thermometer for the QGP formed

Participants listen to Pol-Bernard Gossiaux, of Subatech Nantes, during his talk on "Heavy-quark quenching from RHIC to LHC". (Image credit: Ivar Pel.)

in heavy-ion collisions. Whatever happens, the workshop has provided an excellent framework to discuss this exciting theoretical work and trigger some fruitful ideas for its future development.

The observed signals for the QGP are expected to be even stronger in PbPb collisions at $\sqrt{s_{NN}} = 5.1$ TeV (foreseen in 2015) and allow the properties of the QGP to be characterized further. Proton–lead data are urgently needed to measure the contribution from the effects in cold nuclear matter, such as nuclear shadowing and Cronin enhancement. The experimental teams at the LHC and at RHIC are working on upgrades of the inner tracking systems of their detectors, aiming for an improved resolution in impact parameter, which will make the measurement of open beauty in heavy-ion collisions feasible in the near future.

● The organizers would like to thank the Lawrence Berkeley National Laboratory and the Foundation for Fundamental Research on Matter (FOM) for financial support.

● Further reading

For more about the conference and for slides of the plenary presentations, see http://indico.cern.ch/event/HQP2012.

Résumé

Charme et beauté à Utrecht

Les saveurs lourdes étaient au centre d'un atelier international tenu en novembre dernier à l'Université d'Utrecht. Le 5e atelier international sur la production de quarks lourds dans les collisions d'ions lourds a été l'occasion d'une discussion animée, où il a été question de l'interprétation des mesures actuelles concernant les saveurs lourdes apparentes et cachées dans les collisions d'ions lourds de haute énergie. L'atelier a attiré plus de 70 chercheurs du monde entier. Parmi les sujets abordés, les résultats récents et les futures améliorations et expériences au LHC du CERN, à l'accélérateur RHIC de Brookhaven et à l'installation de recherche sur les antiprotons et les ions de Darmstadt, ainsi que certains développements théoriques.

Hendrik van Hees, Frankfurt Institute of Advanced Studies, **Paul Kuijer**, Nikhef, **André Mischke**, Utrecht University, and **Enrico Scomparin**, INFN-Torino.

The incurable attraction of physics

How a love of CERN and literature came together in the life of a Spanish particle physicist.

A nobel gas, a missing scientist and an underground laboratory. It could be the starting point for a classic detective story. But a love story? It seems unlikely. However, add in a back-story set in Spain during General Franco's rule, plus a "eureka" moment in California, and the ingredients are there for a real romance – all of it rooted firmly in physics.

When Spanish particle-physicist Juan José Gómez Cadenas arrived at CERN as a summer student, the passion that he already had for physics turned into an infatuation. Thirty years later and back in his home country, Gómez Cadenas is pursuing one of nature's most elusive particles, the neutrino, by looking where it is expected not to appear at all – in neutrinoless double-beta decay. Moreover, fiction has become entwined with fact, as he was recently invited to write a novel set at CERN. The result, *Materia Extraña* (Strange matter), is a scientific thriller that has already been translated into Italian.

JJ Gómez Cadenas: a passion for CERN, neutrinos – and writing. (Image credit: Jorge Quiñoa & Jot Down.)

Critical point

"Particle physicists were a rare commodity in Spain when the country first joined CERN in 1961," Cecilia Jarlskog noted 10 years ago after a visit to "a young and rapidly expanding community" of Spanish particle physicists (*CERN Courier* December 2003 p30). Indeed, the country left CERN in 1969, when Juan was only nine years old and Spain was still under the Franco regime. Young Juan – or "JJ" as he later became known – initially wanted to become a naval officer, like his father, but in 1975 he was introduced to the wonders of physics by his cousin; Bernardo Llanas had just completed his studies with the Junta de Energía Nuclear (the forerunner of CIEMAT, the Spanish research centre for energy, the environment and technology) at the same time as Juan Antonio Rubio, who was to do so much to re-establish particle physics in Spain. The young JJ set his sights on the subject – "Suddenly the world became magic," he recalls, "I was lost to physics" – and so began the love affair that was to take him to CERN and, in a strange twist, to write his first novel.

The critical point came in 1983. JJ was one of the first Spanish students to gain a place in CERN's summer student programme when his country rejoined the organization. It was an amazing time to be at the laboratory: the W and Z bosons had just been discovered and the place was buzzing. "I couldn't believe this place, it was the beginning of an absolute infatuation," he says. That summer he met two people who were to influence his career:

It was an amazing time to be at CERN: the W and Z had just been discovered and the place was buzzing.

"My supervisor, Peter Sonderegger, with whom I learnt the ropes as an experimental physicist, and Luis Álvarez-Gaume, a rising star who took pity on the poor, hungry fellow-Spaniard hanging around at night in the CERN canteen." After graduating from Valencia University, JJ's PhD studies took him to the DELPHI experiment at CERN's Large Electron–Positron collider. With the aid of a Fulbright scholarship, ▷

he then set off for America to work on the Mark II experiment at SLAC. From there it was back to CERN and DELPHI again, but in 1994 he left once more for the US, this time following his wife, Pilar Hernandez, to Harvard. An accomplished particle-physics theorist, she converted her husband to her speciality, neutrino physics, thus setting him on the trail that would lead him through the NOMAD, HARP and K2K experiments to the challenge of neutrinoless double-beta decay.

The neutrinoless challenge

Established for 15 years as professor of physics at the Institute of Nuclear and Particle Physics (IFIC), a joint venture between the University of Valencia and the Spanish research council (CSIC), he is currently leading NEXT – the Neutrino Experiment with a Xenon TPC. The aim is to search for neutrinoless double-beta decay using a high-pressure xenon time-projection chamber (TPC) in the Canfranc Underground Laboratory in the Spanish Pyrenees. JJ believes that the experiment has several advantages in the hunt for this decay mode, which would demonstrate that the neutrino must be its own antiparticle, as first proposed by Ettore Majorana (whose own life ended shrouded in mystery). The experiment uses xenon, which is relatively cheap and also cheap to enrich because it is a nobel gas. Moreover, NEXT uses gaseous xenon, which gives 10 times better energy resolution for the decay electrons than the liquid form. By using a TPC, it also provides a topological signature for the double-beta decay.

The big challenge was to find a way to amplify the charge in the xenon gas without inducing sparks. The solution came when JJ talked to David Nygren, inventor of the TPC at Berkeley. "It was one of those eureka moments," he recalls. "Nygren proposed using electroluminescence, where you detect light emitted by ionization in a strong field near the anode. You can get 1000 UV photons for each electron. He immediately realized that we could get the resolution that way." JJ then came up with an innovative scheme to detect those electrons in the tracking plane using light-detecting pixels (the silicon photomultiplier) – and the idea for NEXT was born. "It is hard for me not to believe in the goddess of physics," says JJ. "Every time that I need help, she sends me an angel. It was Abe Seiden in California, Gary Feldman in Boston, Luigi di Lella and Ormundur Runolfson at CERN, Juan Antonio Rubio in Spain … and then Dave. Without him, I doubt NEXT would have ever materialized." The collaboration now involves not only Spain and the US but also Colombia, Portugal and Russia. The generous help of a special Spanish funding programme, called CONSOLIDER-INGENIO, provided the necessary funds to get it going. "More angels came to help here," he explains, "all of them theorists: José Manuel Labastida, at the time at the ministry of science, Álvaro de Rújula, my close friend Concepción González-García … really, the goddess gave us a good hand there."

Despite the financial problems in Spain, JJ says that "there is a lot of good will" in MINECO, the Ministry of Economy, which currently handles science in Spain. He points out that there has already been a big investment in the experiment and that there is full support from the Canfranc Laboratory. He is particularly grateful for the "huge support and experience" of Alessandro Bettini, the former director of the Gran Sasso National Laboratory in Italy, who is now in charge at Canfranc. JJ finds Bettini and Nygren – both in their mid-seventies – inspirational characters, calling them the "Bob Dylans" of particle physics. Indeed, he set up an interview with both of them for the online cultural magazine, *Jotdown* – where he regularly contributes with a blog called "Faster than light".

In many ways, JJ's trajectory through particle physics is similar to that of any talented, energetic particle physicist pursuing his passion. So what about the novel? When did an interest in writing begin? JJ says that it goes back to when his family eventually settled in the town of Sagunto, near Valencia, when he was 15. An ancient city where modern steel-making stands alongside Roman ruins, he found it "a crucible of ideas", where writers and artists mingled with the steel-workers, who wanted a more intellectual lifestyle for their children – especially after the return of democracy with the new constitution in 1978, following Franco's death. JJ started writing poetry while studying physics in Sagunto, and when physics took him to SLAC in 1986, as a member of Stanford University, he was allowed to sit in on the creative-writing workshop. "I was not only the only non-native American but also the only physicist," he recalls. "I'm not sure that they knew what to make of me." Years later, he continued his formal education as a writer at the prestigious Escuela de Letras in Madrid.

A novel look at CERN

Around 2003, CERN was starting to become bigger news, with the construction of the LHC, experiments on antimatter and an appearance in Dan Brown's mystery-thriller *Angels & Demons*. Having already written a book of short stories, *La agonía de las libélulas* (Agony of the dragonflies), published in 2000, JJ was approached by the Spanish publisher Espasa to write a novel that would involve CERN. Of course, the story would require action but it would also be a personal story, imbued with JJ's love for the place. *Materia Extraña*, published in 2008, "deals with how someone from outside tries to come to grips with CERN," he explains, "and also with the way that you do science." It gives little away to say that at one and the same time it is CERN – but not CERN. For example, the director-general is a woman, with an amalgam of the characteristics that he observes to be necessary for women to succeed in physics. "The novel was presented in Madrid by Rubio," says JJ. "At the time, we couldn't guess he had not much time left." (Rubio was to pass away in 2010 (*CERN Courier* March 2010 p35).)

It was one of those eureka moments. Nygren proposed using electro-luminescence.

When asked by Espasa to write another book, JJ turned from fiction to fact and the issue of energy. Here he encountered "a kind of Taliban of environmentalism" and became determined to argue a more rational case. The result was *El ecologista nuclear* (*The Nuclear Environmentalist*, now published in English) in which he sets down the issues surrounding the various sources of energy. Comparing renewables, fossil fuels and nuclear power, he puts forward the case for an approach based on diversity and a mixture of sources. "The book created a lot of interest in intellectual circles in Spain," he says. "For example, Carlos Martínez, who was president of CSIC and then secretary of state (second to the minister) liked it quite a bit. Cayetano López, now director of CIEMAT, and an authority in the field, was kind enough to present it in Madrid. It has made some impact in trying to put nuclear energy into perspective."

So how does JJ manage to do all of this while also developing and promoting the NEXT experiment? "The trick is to find time," he reveals. 'We have no TV and I take no lunch, although I go for a swim." He is also one of those lucky people who can manage with little sleep. "I write generally between 11 p.m. and 2 a.m.," he explains, "but it is not like a mill. I'm very explosive and sometimes I go at it for 12 hours, non-stop."

He is now considering writing about nuclear energy, along the lines of the widely acclaimed *Sustainable Energy – without the hot air* by Cambridge University physicist David MacKay, who is currently the chief scientific adviser at the UK's Department of Energy and Climate Change. "The idea would be to give the facts without the polemic," says JJ, "to really step back." He has also been asked to write another novel, this time aimed at young adults, a group where publisher Espasa is finding new readers. While his son is only eight years old, his daughter is 12 and approaching this age group. This means that he is in touch with young-adult literature, although he finds that at present "there are too many vampires" and admits that he will be "trying to do better". That he is a great admirer of the writing of Philip Pullman, the author of the bestselling trilogy for young people, *His Dark Materials*, can only bode well.

● For more about the NEXT experiment see the recent CERN Colloquium by JJ Gómez Cadenas at http://indico.cern.ch/conferenceDisplay.py?confId=225995. For a review of *El ecologista nuclear* see p47 of this issue.

Résumé

Une passion dévorante pour la physique

Lorsque Juan José Gómez Cadenas, physicien des particules, quittant son Espagne natale, arriva au CERN comme étudiant d'été, son intérêt pour la physique devint une vraie passion. Trente ans plus tard, de retour dans son pays, il traque une particule insaisissable, le neutrino, en la cherchant là où elle n'est pas censée se trouver : dans la double désintégration bêta sans émission de neutrino. Intéressé par la fiction autant que par la réalité, il a publié un roman dont l'action se passe au CERN, puis, plus récemment, un essai sur les choix en matière d'énergie pour le monde. Dans cet entretien, il nous parle de son amour de la physique et de l'écriture.

Christine Sutton, CERN.

Work for the LHC's first long shutdown gets under way

After providing physicists with huge quantities of data, it is time for the LHC to get a facelift.

The LHC has been delivering data to the physics experiments since the first collisions in 2009. Now, with the first long shutdown, LS1, which started on 13 February, work begins to refurbish and consolidate aspects of the collider, together with the experiments and other accelerators in the injections chain.

LS1 was triggered by the need to consolidate the magnet interconnections so as to allow the LHC to operate at the design energy of 14 TeV in the centre-of-mass for proton–proton collisions. It has now turned into a programme involving all of the groups that have equipment in the accelerator complex, the experiments and the infrastructure systems. LS1 will see a massive programme of maintenance for the LHC and its injectors in the wake of more than three years of operation without the long winter shutdowns that were the norm in the past.

The main driving effort will be the consolidation of the 10,170 high-current splices between the superconducting magnets. As many as 1000–1500 splices will need to be redone and more than 27,000 shunts added to overcome possible problems with poor contacts between the superconducting cable and the copper stabilizer that led to the breakdown in September 2008 (*CERN Courier* September 2010 p27).

The teams will start by opening up the interconnections between each of the 1695 main magnet cryostats. They will repair and consolidate around 500 interconnections at a time, in work that will gradually cover the entire 27-km circumference of the LHC. The effort on the LHC ring will also involve the exchange of 19 magnets, consolidation of the cryogenic feed boxes and installation of pressure-relief valves on the sectors that have not yet been equipped with them (*CERN Courier* April 2009 p6).

The Radiation to Electronics project (R2E) will see the protection of sensitive electronic equipment optimized by relocating the equipment or by adding shielding. Nor will work during LS1 be confined to the LHC. Major renovation work is scheduled, for example, for the Proton Synchrotron, the Super Proton Synchrotron and the LHC experiments.

Preparations for LS1 started more than three years ago, with the detailed planning of manpower and other resources. For example, Building 180 on the Meyrin site at CERN recently became a hive of activity as a training centre for the technicians who are implementing the various repairs and modifications. The pictures shown here give the flavour of this activity.

● More detailed articles on the work being done during LS1 will appear in the coming months. For news of the activities, watch out for articles in *CERN Bulletin* at http://cds.cern.ch/journal/CERNBulletin/2013/06/News%20Articles/?ln=en.

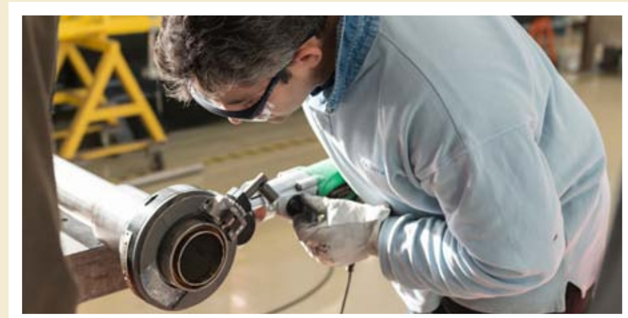
A view of the Large Magnet Facility in Building 180. To the left are spare cryomagnets, with the welding press on the right and the mock-up of a magnet string for training purposes just behind.

Applying electrical insulation to a busbar to equip a mock-up.

One of the workshops where the technology to consolidate the superconducting splices is being prepared.

Plug-in modules ready to equip the training mock-ups.

Welding is one of the skills needed for the refurbishment.



The cutting tool used to open the busbar lines.

Spin physics in Dubna

Experts from around the world travelled to Russia for the biennial symposium on spin.

Participants at the unveiling of the monument to Vladimir Veksler.

SPIN 2012, the 20th International Symposium on Spin Physics, took place at the Joint Institute for Nuclear Research (JINR) in Dubna on 17–22 September. Around 300 participants attended from JINR and institutes in 22 countries (mainly Germany, Italy, Japan, Russia and the US). It consisted of a traditional mix of plenary and parallel sessions. Presentations covered the spin structure of hadrons, spin effects in reactions with lepton and hadron beams, spin physics beyond the Standard Model and future experiments, as well as the techniques of polarized beams and targets, and the application of spin phenomena in medicine and technology.

The symposium began with a focus on work at Dubna, starting with the unveiling of a monument to Vladimir Veksler, who invented the principle of phase stability (independently from Edwin McMillan in the US) and founded the 10 GeV Synchro-phasotron in Dubna in 1955. Talks followed about the future projects to be carried out at JINR's newest facility, the Nuclotron-based Ion Collider fAcility (NICA). The complex will include an upgraded superconducting synchrotron, Nuclotron-M, with an area for fixed-target experiments, as well as a collider with two intersections for polarized protons (at 12 GeV per beam) or deuterons and nuclei (5 A GeV per beam). It will provide opportunities for a range of polarization studies to complement global data and will particularly help to solve the puzzles of spin effects that have been awaiting solutions since the 1970s. The spin community at the symposium supported the plans for these unique capabilities, and JINR's director, Victor Matveev, announced that the project is ready to invite international nominations for leading positions in the spin programme at NICA.

The experimental landscape

In the US, Jefferson Lab's programme of experiments on generalized parton distributions (GPDs) will be implemented with upgraded detectors and an increase in the energy of the Continuous Electron Beam Accelerator Facility from 6 GeV up to 12 GeV (*CERN Courier* November 2012 p30). The laboratory is also considering the construction of a new synchrotron to accelerate protons and nuclei up to 250 GeV before collision with 12 GeV electrons. In a similar way, a new 10–30 GeV electron accelerator is being proposed at Brookhaven National Laboratory to provide collisions between electrons and polarized protons and ions, including polarized ^{3}He nuclei, at the Relativistic Heavy-Ion Collider (RHIC). The aim will be to investigate the spin structure of the proton and the neutron.

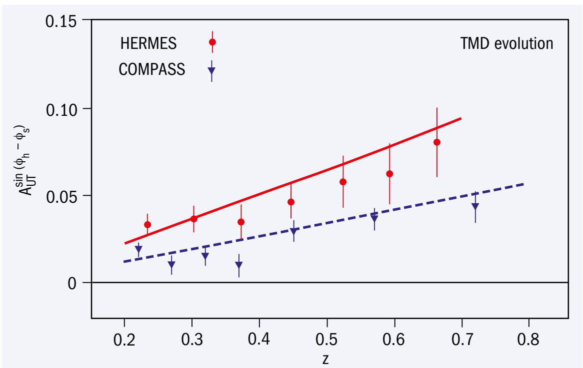


Fig. 1. Comparison of Sivers parton distribution functions from COMPASS and HERMES using the new evolution equation.

At CERN, the COMPASS-II project has been approved, firstly to study Drell-Yan muon-pair production in collisions of pions with polarized nucleons, to investigate the nucleon's parton distribution functions (PDFs). A second aim is to study GPDs via the deeply virtual Compton-scattering processes of exclusive photon and meson production. The latter processes will provide the possibility for measuring the contribution of the orbital angular momenta of quarks and gluons to the nucleon spin. The Institute of High Energy Physics (IHEP), Protvino, has a programme at the U-70 accelerator for obtaining polarized proton and antiproton beams from Λ decay for spin studies at the SPASCHARM facility, which is currently under construction.

The participants heard with interest the plans to construct dedicated facilities for determining the electric dipole moment (EDM) of the proton and nuclei, with proposals by the Storage Ring EDM collaboration at Brookhaven and the JEDI collaboration at Jülich. The dipole moment of fundamental particles violates both parity and time-reversal invariance. Its detection would indicate the violation of the Standard Model and would, in particular, make it ▷

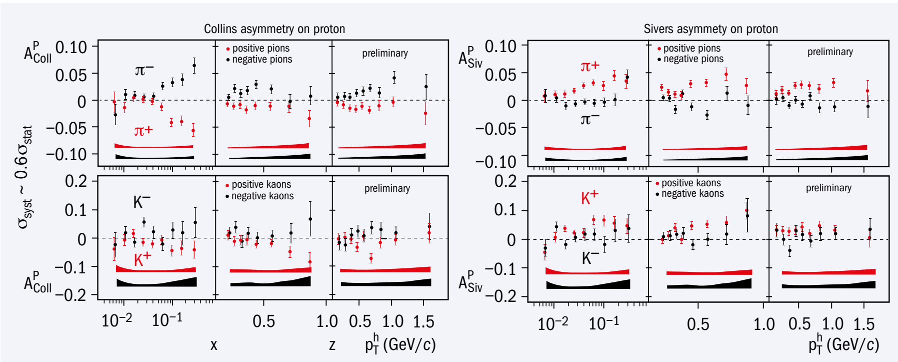


Fig. 2. The Collins and Sivers asymmetries measured by COMPASS.

possible to approach the problem of understanding the baryon asymmetry of the universe. The proposed experiments would reduce the measurement limit on the deuteron EDM down to 10^{-29} e cm.

Classical experiments studying the nucleon spin structure at high energies use both lepton scattering on polarized nucleons (e.g. in HERMES at DESY, COMPASS and at Jefferson Lab) and collisions of polarized hadrons (at RHIC, IHEP and JINR). A unified description of these different high-energy processes is becoming possible within the context of QCD, the theory of strong interactions. Related properties, such as factorization, local quark–hadron duality and asymptotic freedom, allow the calculation of the characteristics of the process within the framework of perturbation theory. At the same time, PDFs, correlation and fragmentation functions are not calculable in perturbative QCD, but being universal they should be either parameterized and determined using various processes or calculated within some model approaches. A number of talks at the symposium were devoted to the development and application of such models.

Theory confronts experiment

Experiments involving spin have brought about the demise of more theories than any other single physical parameter. Modern theoretical descriptions of spin-dependent PDFs, especially those including the internal transverse-parton motion, were discussed at the symposium. In this case, the number of PDFs increases and the picture that is related to them loses – to a considerable degree – the simplicity of a parton model with its probabilistic interpretation. One of the difficulties here concerns how the PDFs evolve with a change in the wavelength of the probe particle. A new approach to solving this problem was outlined and demonstrated for the so-called Sivers asymmetry measured in data from the HERMES and COMPASS experiments (figure 1, p29).

The helicity distributions of the quarks in a nucleon are the most thoroughly studied so far. The results of the most accurate measurements by COMPASS, HERMES and the CLAS experiment at Jefferson Lab were presented by the collaborations. The present-day experimental data are sufficiently precise to include them in QCD analysis. Two new alternative methods for the QCD analysis of deep-inelastic scattering (DIS) and semi-inclusive DIS (SIDIS) data allow a positive polarization of strange quarks to be excluded with a high probability. As for the gluon polarization, the results of its direct measurement by the COMPASS experiment, which are confirmed by the PHENIX and STAR experiments at RHIC, also agree with QCD analysis. The low value of gluon polarization indicates that its contribution to nucleon spin is not enough to resolve the so-called nucleon-spin crisis. Hopes to overcome this crisis are now connected to the possible contributions of the orbital angular momenta of quarks and gluons, to be measured from GPDs. There were talks on different theoretical aspects of GPDs, as well as experimental aspects of their measurement, in the context of the HERMES, CLAS and COMPASS experiments.

Other important spin distribution functions manifest themselves in the lepton DIS off transversely polarized nucleons. The processes in which the polarization of only one particle (initial or final) is known are especially interesting. However, although relatively simple from the point of view of the experiment, they are complicated from the theoretical point of view (such complementarities frequently occur). These single-spin asymmetries are related to T-odd effects, i.e. they seemingly break invariance with respect to time reversal. However, it is a case of "effective breaking" – that is, it is not related to a true non-invariance of a fundamental interaction (here, the strong interaction, described by QCD) with respect to time reversal but to its simulation by the effects of re-scattering in the final or initial states. The single asymmetries have been studied by theorists for more than 20 years. These studies have received a fresh impetus in recent years in connection with new experimental data on single-spin asymmetries in the semi-inclusive electroproduction of hadrons off longitudinally and transversely polarized and unpolarized nucleons.

Reports from the COMPASS collaborations on transverse-momentum-dependent (TMD) asymmetries were one of the highlights of the symposium. The experiment is studying as many as 14 different TMD asymmetries. Two of them, the Collins and Sivers asymmetries (figure 2) – which are responsible for the left–right asymmetries of hadrons in the fragmentation of transversely polarized quarks and quark distributions in transversely polarized nucleons – are now definitely established in the global analysis of all of the available data, although

The helicity distributions of the quarks in a nucleon are the most thoroughly studied so far.

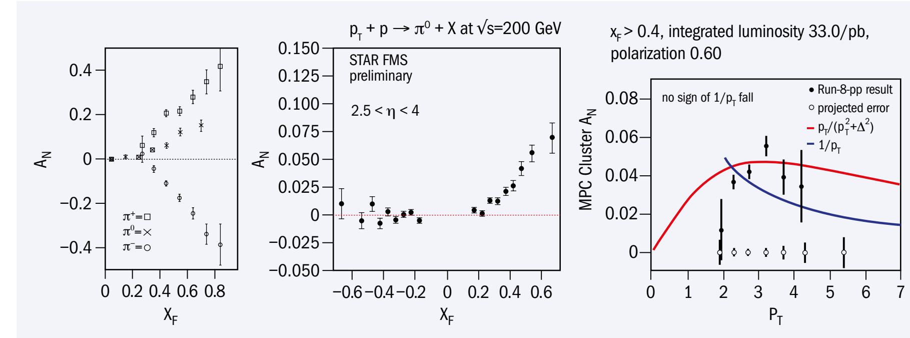


Fig. 3. The A_N asymmetries observed at Fermilab (left) and at RHIC (centre and right).

other TMD effects require further study. The results of studies of the transverse structure of the proton at Jefferson Lab were also presented at the symposium.

The PHENIX and STAR collaborations have new data on the single-spin asymmetries of pions and η-mesons produced in proton–proton collisions at 200 GeV per beam at RHIC, with one of the beams polarized and the other unpolarized. They observe amazingly large asymmetries in the forward rapidity region of the fragmenting polarized or unpolarized protons, with a fall to zero in the central rapidity region. A similar effect was observed earlier at Protvino and at Fermilab, but at lower energies, thus confirming energy independence (figure 3). In addition, there is no fall with rising transverse momentum in the values of the asymmetry measured at RHIC. The particular mechanism for these asymmetries remains a puzzle so far.

So although single-spin asymmetries on the whole are described by existing theory, developments continue. The T-odd distribution functions involved lose the key property of universality and become "effective", that is, dependent on the process in which they are observed. In particular, the most fundamental QCD prediction is the change of sign of the Sivers PDF determined from SIDIS processes and from Drell-Yan pair-production on a transversely polarized target. This prediction is to be checked by the COMPASS-II experiment as well as at RHIC, NICA and in the PANDA and PAX experiments at the Facility for Antiproton and Ion Research.

New data from Jefferson Lab on measurements of the ratio of the proton's electric and magnetic form factors performed by the technique of recoil polarization gave rise to significant interest and discussions at the symposium. The previous measurements from Jefferson Lab showed that this ratio is not constant, as had been suggested for a long time, but decreases linearly with increasing momentum transfer, Q^2 – the so-called "form factor crisis". New data from the GEp(III) experiment indicate a flattening of this ratio in the region of $Q^2 = 6–8\,\mathrm{GeV}^2$. The question of whether this behaviour is a result of an incomplete calculation of radiative corrections – in particular, two-photon exchange – remains open.

The symposium enjoyed hearing the first results related to spin physics from experiments at CERN's LHC. In particular, many discussions focused on the role of spin in investigating the recently discovered particle with a mass of 125 GeV, which could be the Higgs boson, as well as in studies of the polarization of W and Z bosons, and in heavy-quark physics. A number of talks were dedicated to the opportunities for theory related to searches for the Z' and other exotics at the LHC and the future electron–positron International Linear Collider.

On the technical side there was confirmation of the method of obtaining the proton-beam polarization at the COSY facility in Jülich by spin filtration in the polarized gas target. This method can also be used for polarization of an antiproton beam, which will be important for measurements of different spin distributions in the nucleon via Drell-Yan muon-pair production in polarized proton–antiproton collisions in the PANDA and PAX experiments. There were also discussions on sources of polarized particles, the physics of polarized-beam acceleration, polarimeters and polarized-target techniques. In addition, there were reports on applications of hyperpolarized ^{3}He and ^{19}F in different fields of physics, applied science and medicine.

The main results of the symposium were summarized in an excellent concluding talk by Franco Bradamante from Trieste. For a complete list of speakers and talks see http://theor.jinr.ru/~spin2012/programme.html. The proceedings will be published in special volumes of *Physics of Elementary Particles and Atomic Nuclei*. The International Committee on Spin Physics, which met during the symposium, emphasized the excellent organization and success of the meeting in Dubna and decided that the 21st Symposium of Spin Physics will take place in Beijing in September 2014.

Résumé

La physique du spin à Doubna

SPIN2012, l'édition 2012 du colloque biennal sur le spin, a eu lieu à l'Institut unifié de recherche nucléaire (JINR) à Doubna, en septembre. Réunissant quelque 300 participants issus de 22 pays, essentiellement de Russie, des États-Unis, d'Allemagne, du Japon et d'Italie, le colloque avait adopté la formule traditionnelle d'alternance entre sessions plénières et sessions parallèles. Après un point sur les travaux réalisés à Doubna, le colloque a évoqué les nouvelles des expériences dans le monde entier, y compris les premiers résultats relatifs à la physique du spin en provenance du LHC, au CERN. Il y a été question également des développements théoriques ainsi que des futures expériences et des techniques pour les faisceaux et cibles polarisés

Anatoly Efremov, **Richard Lednický**, **Igor Savin** and **Oleg Teryaev**, JINR.

Faces & Places

Appointment

Brookhaven has new leader for nuclear and particle physics

Nuclear physicist Berndt Mueller is to lead the physics programmes at Brookhaven National Laboratory, having taken over as the associate laboratory director (ALD) for nuclear and particle physics as of 1 January. Mueller has a long collaborative association with Brookhaven and brings world-class experience to his new post as both a scientist and a manager of major research initiatives.

With a PhD in theoretical physics from Goethe University in Frankfurt, as well as postgraduate studies at Yale University and the University of Washington, Mueller has served on many physics review panels for the US Department of Energy and the National Science Foundation. He is currently chair-elect of the division of nuclear physics of the American Physical Society. He recently co-authored a paper for the journal *Science*, reviewing the scientific achievements of the laboratory's Relativistic Heavy-Ion Collider (RHIC) and outlining the complementary physics opportunities for the next decade of experiments at RHIC and at the LHC at CERN.

Berndt Mueller is Brookhaven's new associate laboratory director for nuclear and particle physics. (Image credit: BNL.)

Mueller replaces physicist Steve Vigdor, who retired at the end of 2012 after five years as ALD. Vigdor had advanced the research programme at RHIC, guided the laboratory's participation in the ATLAS experiment and developed programmes in cosmology, astrophysics and neutrino research.

Currently a James B Duke Professor and the director of the Centre for Theoretical and Mathematical Sciences at Duke University, Mueller will continue his work there for the remainder of the current academic year, splitting his time between Duke and Brookhaven for the first five months. During this transition period, Brookhaven's David Lissauer will act as interim ALD, sharing responsibilities and bringing Mueller up to speed on the laboratory's existing operations and latest initiatives.

Italy

INFN inaugurates new national centre in Trento

Francesco Profumo, Italy's Minister for Education, Research and University, speaks at the inauguration of the INFN national centre in Trento. (Image credit: University of Trento.)

The INFN has established a new national centre at Trento, northern Italy, dedicated to particle physics and the development of cutting-edge technologies in sensors, space research, supercomputing and biomedicine. The Trento Institute for Fundamental Physics and Applications (TIFPA) is a result of collaboration between the INFN, the University of Trento, the Bruno Kessler Foundation (FBK) and the Trento Provincial Agency for Proton Therapy (ATreP).

The new centre will deal with research into fundamental physics as well as innovation and technology transfer by exploiting the existing infrastructures, skills and human resources of the project's partners in Trento and by expanding specific areas of action. It will, for instance, count on the infrastructures of the Centre for Materials and Microsystems – which built the silicon detectors for the AMS experiment on the International Space Station and for the ALICE experiment at CERN – and of the European Centre for Theoretical Physics of the FBK and use the new proton-therapy machine that will become operational by the end of 2013.

Francesco Profumo, Italy's Minister for Education, Research and University, spoke at the end of the inauguration ceremony on 15 January, immediately after the INFN, the University of Trento, the BFK and the ATreP signed a declaration of intent. His presence at the event underlined the strategic importance of the initiative, both for the potential for scientific progress and in terms of building synergies among the various institutions. The declaration officially paves the way for further and closer institutional collaborations to be implemented at the cutting-edge centre.

Awards

CERN makes the headlines in 2012

The announcement by the ATLAS and CMS collaborations last July of the discovery of a new particle at CERN's LHC made headlines around the world. These were echoed in December by a number of magazines and newspapers as they published their lists of top news from 2012. The collaborations may not yet have enough information to confirm that the new particle is the long-sought Higgs boson of the Standard Model but the discovery has made an impact beyond just the scientific media, as these example show.

Starting with scientific magazines, *Science* named the discovery "Breakthrough of the Year, 2012". Their list of runners up included more particle physics with the measurement of θ_{13} – "the last parameter describing how elusive particles called neutrinos morph into one another as they zip along at near-light speed" – by the Daya Bay Reactor Neutrino Experiment in China (*CERN Courier* May 2012 p6). *Physics World* also made its award for the 2012 Breakthrough of the Year "to the ATLAS and CMS collaborations at CERN for their joint discovery of a Higgs-like particle at the Large Hadron Collider".

Nature named CERN's director-general, Rolf Heuer, as one of its "10 people who matter" in 2012, calling him the "Higgs diplomat" and saying that his "gentle nudging … ensured that the world heard about the discovery" of the new particle. (In 2011, CERN's Mike Lamont had featured as the "Higgs mechanic"). While *TIME* named the President Barack Obama its "Person of the Year", it selected the current spokesperson for the ATLAS collaboration, Fabiola Gianotti, as a runner-up, alongside Tim Cook, Malala Yousafzai, and Mohamed Morsi. The magazine also named the new particle as "Particle of the year", hailing its discovery as "one of science's greatest achievements". *National Geographic* was another prestigious popular magazine to recognize the achievement, ranking the discovery seventh in its "Top 10 Discoveries of 2012".

Last but not least the Spanish newspaper *El Mundo* pronounced CERN "City of the year 2012", with its "machine that unveiled the cement of the universe".

Cyprus honours Herwig Schopper

On 12 December, in a small ceremony at the Presidential Palace in Nicosia, the president of Cyprus, Demetris Christofias, awarded Herwig Schopper the rare distinction of the Grand Cross of the Order of Merit of the Republic of Cyprus. Schopper, who was director-general of CERN in the years 1981–1988, received the award principally for his contribution since 2001 to the planning and development of the Cyprus Institute where he is president of the Scientific Advisory Council. He was also honoured for his involvement as founder and first president of the International Council of SESAME, the synchrotron radiation laboratory in Jordan. Edouard Brézin, former president of the French Academy of Sciences, was also honoured at the same ceremony.

Demetris Christofias, left, presents the Grand Cross of the Order of Merit of the Republic of Cyprus to Herwig Schopper. (Image credit: Cyprus Institute.)

Academy of Lyon presents the 2012 Prix Thibaud

Left: Jacques-Emmanuel Marteau. (Image credit: J-E Marteau.) Right: Sandrine Laplace (left) and Aurélien Barrau at the prize ceremony. (Image credit: P Salati/IN2P3.)

At a ceremony on 18 December at the Hotel de Ville, Lyon, chaired by Cédric Villani, winner of the Fields Medal 2010, the 2012 Prix Thibaud was awarded to Aurélien Barrau, Sandrine Laplace and Jacques-Emmanuel Marteau. They receive the prize for their high-quality contributions to nuclear, particle and astroparticle physics.

Barrau is professor at the Université Joseph Fourier and a researcher in the Laboratory for Subatomic Physics and Cosmology, Grenoble, where he specializes in cosmology and astroparticle physics. Laplace is a CNRS researcher at the Laboratory of Nuclear Physics and High-Energy Physics, Paris, and she works on the ATLAS experiment at CERN's LHC, specializing in the electromagnetic calorimeter and the decay of the Higgs boson into two photons. Marteau, associate professor at the Institute of Nuclear Physics of Lyon, specializes in neutrino physics and is a member of the T2K collaboration; he was a member of the OPERA collaboration up until 2012.

The prize, in honour of nuclear physicist and former president of the Académie des Sciences, Belles-Lettres et Arts de Lyon, Jean Thibaud (1901–1960), has been awarded biannually since 1963. Candidates are European experimental or theoretical physicists, aged between 30 and 40, active in the fields of nuclear, particle or astroparticle physics and engaged by a French research organization and laboratory.

Outreach

ALBA opens its doors to the public

The Spanish Synchrotron Radiation Facility, ALBA, held its first public open day on 15 December. More than 1000 visitors, mainly from Barcelona and the surrounding region, came to the laboratory on a sunny Mediterranean winter's day; visits by hundreds more had to be postponed for future events.

The lucky ones enjoyed an itinerary round the laboratory's installations, which took them to see the view from the top of the accelerator tunnel, past the experiment "hutches" and through one of the control rooms. There was also an opportunity to look closely at a copy of one arc of the ring, a monochromator and a radio-frequency cavity. The tour was enhanced by explanatory panels that showed the principles of particle accelerators, the production of synchrotron radiation and its uses, as well as many scientific applications of synchrotron radiation.

ALBA is a third-generation synchrotron light-source facility situated at Cerdanyola del Vallès, Barcelona (*CERN Courier* November 2008 p31). It began operation for users during 2012 and the seven Phase I beamlines are now operational. The accelerator routinely delivers a stable 3 GeV electron current of 100 mA, with the implementation of top-up and higher currents envisaged early in 2014. The first paper with scientific results based on data from ALBA – on inorganic chemistry – was published in December 2012.

The complete success of the open day was made possible thanks to the volunteer participation of ALBA staff, whose enthusiasm, professionalism and joy in showing their daily work to visitors.

Staff volunteers were on hand on ALBA's first open day to explain the exhibits, including a copy of one arc of the machine. (Image credit: ALBA.)

Google Science Fair seeks the scientists of tomorrow

At the end of January, Google launched its third annual Google Science Fair in partnership with CERN, LEGO, *National Geographic* and *Scientific American* magazines. The Google Science Fair is an international competition that encourages students between the ages of 13 to 18 from all around the world to perform science experiments or create engineering projects and submit them online to compete for prizes, scholarships and once-in-a-lifetime experiences, including a trip to CERN (*CERN Courier* September 2012 p68 and January/February 2013 p42).

As with the second science fair in 2012, Fermilab is teaming up with CERN to offer a prize of experiencing a week as an international particle physicist, shadowing a physicist mentor at Fermilab and then travelling with their mentor to CERN. Previous winners have tackled cancer diagnosis and treatment, figured out more efficient ways to farm as well as explored the natural world around them.

● The competition is open until 30 April. Interested students and teachers should visit www.googlesciencefair.com.

Please note that the competition is not open to the relatives of employees of CERN, Fermilab or Google.

Google Science Fair tells 13–18 year olds that "It's your turn to change the world".

Meetings

FPCP 2013, the **11th conference on Flavor Physics & CP Violation 2013** will take place on 19–24 May in Búzios, Rio de Janeiro, Brazil. The aim of the meeting is to review developments – theoretical and experimental – related to the physics of heavy flavours. There will be updates on many topics, including CP violation, rare decays, spectroscopy, CKM elements and the potential for studies of heavy flavour decays to help unravel any new physics seen directly at the LHC. For further information and for registration, see http://fpcp2013.if.ufrj.br.

The **2013 Space-Cryogenics Workshop**, "Space Cryogenics at Earth's Last Frontier", is to be held on 23–25 June in Girdwood, Alaska. Sponsored by the NASA Goddard Space Flight Center and the Cryogenic Society of America, the workshop is an opportunity for all of those engaged in low-temperature work to exchange research results and knowledge. All aspects of space cryogenics will be represented, with an emphasis on work related to previous missions as well as future research. For details, see www.spacecryogenicsworkshop.org.

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OBITUARIES

Paul Levaux 1931–2012

Paul Levaux, a long-standing member of the Belgian delegation to CERN's Finance Committee and Council, passed away on 3 December 2012.

Paul Levaux first attended the CERN Council and Finance Committee in June 1970 as an adviser, although his association with CERN goes back to the 1960s. From October 1970 until December 2007 he represented Belgium as a delegate to Council and Finance Committee. He was chair of Finance Committee (1971–1973) and president of Council (1975–1978). He also served as vice-president of Council (1978–1980) with a second term from January 1994 until December 1997.

In addition to holding these important offices, Levaux participated in an extensive number of CERN working groups. In particular, he was a member of the Working Group on Procedures for Payment of Member States' Contributions (2000–2001) and the Working Group for the Review of the Tasks and Working Methods of CERN's Governing Bodies and Committees (July–December 2003), chair of the Study Group on Pension Fund Governance in 2007, and chair of the Working Group on the Procedure for future Elections of the President of Council and the Chairs of the CERN Committees in 2007.

Paul Levaux. (Image credit: E Gröniger-Voss.)

A substantial part of Levaux's time at CERN was devoted to matters relating to the Pension Fund. As chair of the Governing Board of the pension fund in the years 1989–2002, he was responsible for organizing and implementing the new structure of the fund, giving it a greater operational autonomy and placing it under the direct authority of the Council. His services in the pension field were recently called on again when he made an important contribution to the setting-up of the new governance structure for the Pension Fund approved by Council in 2007, whose final report now bears his name as the "Levaux Report". As doyen of Council and Finance Committee by a considerable margin, Levaux's departure as a delegate represented the loss of one of CERN's most distinguished and long-standing member-state representatives, a true *mémoire du CERN*.

Throughout his long association with CERN, Levaux remained a strong supporter of the organization and its activities and in honour of his achievements he was invited back to CERN last June for the Council dinner. Gratifyingly, he lived to witness the first results from the LHC, the announcement of which brought him great satisfaction.

● *CERN management, president and delegates of Council, and his colleagues and friends.*

Gordon Fraser 1943–2013

Gordon Fraser, who was editor of *CERN Courier* for 20 years, passed away on 3 January.

Born in Glasgow, to Ralph Jack Fasht and Ray Braverman, whose parents originally came from Russia, Gordon grew up in the east end of London. His life in physics began at Imperial College London, where he was encouraged to read Paul Dirac's *Principles of Quantum Mechanics* and took mathematics as a special subject. With a demonstrated ability in mathematics, he went on to join the theory group of the future Nobel laureate Abdus Salam and obtained his PhD on diffractive scattering in 1967 under Paul Matthews. Gordon then joined the group of Yuval Ne'eman at Tel Aviv University for two years, before returning to the UK and Sussex University, where he met his future wife, physics postgraduate Gill Harbinson.

A radical change in career soon followed in 1969, when Gordon left physics to become a journalist, at first for *Computer Weekly* in London and later as a freelancer. He moved into scientific editing at the Rutherford Appleton Laboratory in 1975 and it was from there that he was hired to join the publications team at CERN in 1977.

Gordon Fraser.

By 1982 Gordon had become the editor of *CERN Courier*. During his time at the helm, both particle physics and the *Courier* changed considerably. Under his careful stewardship, aspects of publishing were outsourced, leading to an attractive, professional magazine with a worldwide reputation.

These developments required the creativity and sharp writing skills for which Gordon became well known, not only through the *Courier* but also through his books about particle physics. *The Search for Infinity* (with E Lillestøl, I Sellevå) – an illustrated popular introduction to particle physics and cosmology – was translated into nine languages.

Offered a major opportunity by Cambridge ▷

University Press to be editor-in-chief of *The New Physics for the 21st Century* (published in 2006), Gordon took early retirement from CERN in 2002 to concentrate on writing books. A biography of an early mentor, *Cosmic Anger – Abdus Salam, the First Muslim Nobel Scientist* (*CERN Courier* September 2008 p55), followed in 2008.

His most recent work in a sense a tribute to his family's origins and dedicated to his father, was *The Quantum Exodus – Fugitive Jews, the Atomic Bomb, and the Holocaust* (reviewed in *CERN Courier* October 2012 p49).

A well known figure at CERN, Gordon was also a keen runner and he was often seen powering around the Meyrin site on his lunchtime run. He will be missed by many, especially by those who were fortunate enough to have worked with him and witnessed his skill as a writer. He is survived by his father, his wife Gill and two children, Nathalie and Ben.

● *His colleagues and friends.*

Letter

The missing life of DORIS

The article "The three lives of DORIS" (*CERN Courier* December 2012 p 22) briefly summarizes the history of DORIS. We believe the author has forgotten one "life", in the years 1977–1978, when DORIS was upgraded from 3.5 GeV to 10.0 GeV in the centre of mass. Though being only a short life it is worth mentioning for at least three reasons.

First, it enabled a scan of the full range of energies and confirmed that there were no new quarks (below the Y) and strengthened knowledge of the properties of jets from the hadronization of quarks. Second, it allowed the detection of the new Y resonance at 9.46 GeV, which decays mainly strongly and is very narrow, and thereby delivered the necessary confirmation of the new b quark found a year earlier at Fermilab via the Y resonance at 9.5 GeV. Third, through the analysis of the hadronic decays of the Y, it provided first evidence for the decay Y → 3 gluons → 3 jets, for gluon jets and for the spin 1 of the gluon, and hence made an important contribution to the discovery of the gluon, confirming the expectations of QCD.

The reason for forgetting this "life" could be that the author based his article on a book published in 2009, and so missed two more recent papers. In one we put new light on the importance of the PLUTO experiment at DORIS in 1978 in contributing to the discovery of the gluon (Stella and Meyer 2011). The second is an independent review where this new perspective is mainly confirmed (Ali and Kramer 2011, see e.g. p3 and pp20–24 in chapter 4, "Gluon jets in Y decays").

For completeness, we would like to remember not only the results of PLUTO at DORIS but also other "forgotten" experiments: DASP, Crystal Ball, DASPII, DESY-HDD and LENA.

Bruno R Stella (Bruno.Stella@roma3.infn.it) and Hans-Jürgen Meyer (Hans-Juergen.Meyer@ams-soft.de).

● Further reading

A Ali and G Kramer 2011 *Eur. Phys. J.* **H 36** 203.
B Stella and H-J Meyer 2011 *Eur. Phys. J.* **H 36** 243.

Peter Higgs (right), emeritus professor at the University of Edinburgh, has been made a Companion of Honour in recognition of his services to physics in the UK's New Year Honours list for 2013. This honour is restricted to a select group of 65 for achievements in the arts, literature, music, science, politics, industry or religion. Two companions were named for 2012, the other being Lord Sebastian Coe, for his work in bringing the Olympic Games to London and ensuring its success. Lord Coe was a gold medallist over 1500 m in 1980. Higgs' colleague, Alan Walker (left), an honorary fellow at Edinburgh University, was also honoured, as a member of the Order of the British Empire (MBE) for services to science engagement and science education in Scotland.

New products

Intersil Corporation has announced the ISL8225M, a 30A fully encapsulated power module. The ISL8225M can deliver up to 100W-output power from a small 17-mm-square PCB footprint. The two 15A outputs can be used independently or combined to deliver a single 30A output. Current sharing and phase interleaving allow up to six modules to be put in parallel for 180A-output capability. Excellent efficiency and low thermal resistance permit full-power operation without heat sinks or fans. For more information, contact Kelly Maxwell, tel + 1 408 546 3582, e-mail kmaxwell@intersil.com or see www.intersil.com.

Lake Shore Cryotronics Inc has introduced updated specifications for its Model CRX-VF Cryogenic Probe Station, featuring increased maximum magnetic field, improved magnetic field at elevated sample temperatures and improved vacuum performance. The cryogen-free micro-manipulated probe station is used for nondestructive testing of devices on full and partial wafers up to 51 mm in diameter. The maximum magnetic field capability at base temperature has been improved from ±2.25 T to ±2.5 T. For more information, tel +1 614 891 2244, fax +1 614 818 1600, e-mail info@lakeshore.com or visit www.lakeshore.com.

Faces & Places

Luvata has announced Mileon, the longest seamless hollow conductor available on the market. Unlike traditional hollow conductors, Mileon gives manufacturers the option for large continuous coils or the flexibility to specify the optimum length, reducing the required amount of scrap and packaging materials. Mileon hollow conductors are completely jointless and are produced in continuous lengths of hundreds or thousands of metres. Made from high-purity oxygen-free copper, Mileon delivers electrical conductivity of 101–102% IACS and thermal conductivity of 390 W/km. For further details, contact Paula Tappola, tel +358 2 626 6878, e-mail paula.tappola@luvata.com or see www.luvata.com.

Narda Safety Test Solutions presents two new meters for equipment that operates using industrial frequencies. The NIM-511 and NIM-513 are complete hand-held measuring systems that make standards-compliant measurements of electric and magnetic field strength and demonstrate adherence to human safety regulations. The NIM-511 covers the range 300 kHz to 100 MHz, while the NIM-513's sensors cover the range 10 MHz to 42 MHz and are balanced during calibration at the 27.12 MHz frequency used for heat-welding equipment and induction ovens. For further information contact Narda STS at tel +49 7121/9732 0, e-mail support@narda-sts.de or see www.narda-sts.de.

Pfeiffer Vacuum has introduced energy-saving dry pumps A100 L, with a compact design specially developed for flexible integration in semiconductor production facilities. These dry multistage Roots pumps are ideal for clean applications and the fully integrated ES module reduces energy use to a minimum in the low-pressure range, significantly reducing operating costs. Annual savings per pump total up to 7900 kWh. In addition, the final pressure of the A100 L ES is reduced to 7×10^{-4} mbar (hPa), which opens up new potential applications. For details, contact Sabine Neubrand-Trylat, tel +49 6441 802 1223, e-mail Sabine.Neubrand@pfeiffer-vacuum.de or visit www.pfeiffer-vacuum.com.

UltraVolt Inc has announced lower output voltage ranges on its general-purpose bench-top power system, the BT-GP Series, which are now offered at 1 kV, 2 kV, 4 kV and 6 kV of output power at 30 W. The BT-GP Series is ideal for OEM-biasing applications such as air purification, process fluid cleansing, hi pot testing and for laboratory research. The company has also announced that the –I5 and –I10 interface options are now available on its higher voltage modules (10A–25A Series), low-ripple modules (F Option) and standard high-voltage biasing supplies (A Series). For further details, tel +1 631 471 4444 or see www.ultravolt.com.

XP Power has announced the ECP60 series of compact low profile 60 Watt AC/DC power supplies. These units with typically 88% efficiency measure 101.6 × 50.8 × 30.4 mm and fit into an industry standard footprint. With a no-load power consumption of less than 0.5 W the ECP60 series helps to comply with "green" energy-efficiency specifications. The series comprises eight models offering a +5 VDC single output, three dual-output and four triple-output models. For more information, contact Steve Head, tel +44 118 984 5515, e-mail shead@xppower.com or visit www.xppower.com.

Recruitment

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6HG, UK.
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POSTDOC ATLAS.

DESY, Zeuthen location, is seeking:
Postdoctoral Fellow (f/m)

DESY
DESY is one of the world's leading accelerator centres for investigating the structure of matter. DESY develops, builds and operates large accelerator facilities for photon science, particle physics and astroparticle physics.

For the DESY Zeuthen site we are looking for a postdoctoral fellow within the ATLAS group. The group is, together with the Hamburg part, responsible for parts of the operation of the semiconductor tracker (SCT). The group is also active in physics analysis using top quarks. At present we are finishing an analysis on ttbar resonances and plan to analyse top-Higgs couplings.

The position
- Contributions to SCT operation
- Analysis of ttbar resonances and ttH couplings
- Help in the supervision of PhD and master students

Requirements
- PhD in particle physics
- Experience in data analysis and detector operation, ideally within the environment of hadron colliders
- Willingness to collaborate with students

For further information please contact klaus.moenig@desy.de, +49 33762-77271.

Please submit your application including a resume and the usual documents (curriculum vitae, list of publications and copies of university degrees) to the DESY human resources department (recruitment@desy.de). Please arrange for three letters of reference to be sent before the application deadline to the DESY human resource department (recruitment@desy.de).

The position is limited to two years with a possible prolongation of one year. Salary and benefits are commensurate with those of public service organisations in Germany. Classification is based upon qualifications and assigned duties. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women.

Please send your application quoting the reference code, also by email, to:
Deutsches Elektronen-Synchrotron DESY
Human Resources Department | Code: EP004/2013
Notkestraße 85 | 22607 Hamburg | Germany
Phone: +49 40 8998-3392 | Email: recruitment@desy.de
Deadline for applications: 10th March 2013
www.desy.de

The Helmholtz Association is Germany's largest scientific organisation.
www.helmholtz.de
HELMHOLTZ GEMEINSCHAFT

Accelerators | Photon Science | Particle Physics
Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

PARTICLE PHYSICS.

DESY has openings for:
DESY-Fellowships (f/m)

DESY
DESY is one of the world's leading centres for the investigation of the structure of matter. DESY develops, runs and uses accelerators and detectors for photon science and particle physics.

The position
Fellows in experimental particle physics are invited to participate in DESYs particle physics research.
- Analysis and detector-upgrade in the LHC experiments ATLAS and CMS
- Preparation of the International Linear Collider ILC (accelerator and experiments)
- Cooperation in the Analysis Centre of the Helmholtz Alliance "Physics at the Terascale"
- Participation in experiments like ALPS and OLYMPUS
- Cooperation in the BELLE II experiments
- Analysis of HERA data

Requirements
- Ph.D. completed within the last 4 years
- Experience in experimental particle physics

DESY-Fellowships are awarded for a duration of 2 years with the possibility of prolongation by one additional year.

Please submit your application including a resume and the usual documents (curriculum vitae, list of publications and copies of university degrees) to the DESY human resources department. Please arrange for three letters of reference to be sent before the application deadline to the DESY human resource department.

Salary and benefits are commensurate with those of public service organisations in Germany. Classification is based upon qualifications and assigned duties. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women. There is an bilingual kindergarten on the DESY site.

Please send your application quoting the reference code, also by E-Mail to:
Deutsches Elektronen-Synchrotron DESY
Human Resources Department | Code: EM001/2013
Notkestraße 85 | 22607 Hamburg | Germany | Phone: +49 40 8998-3392 |
E-Mail: recruitment@desy.de
Deadline for applications: 31 March 2013
www.desy.de

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HELMHOLTZ ASSOCIATION

PRiSMA

Cluster of Excellence

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

The Faculty of Physics, Mathematics, and Computer Science at the Johannes Gutenberg University of Mainz (JGU) and the PRISMA Cluster of Excellence invite applications for an appointment at the level of

University Professor (W2, tenure track) in Theoretical Particle Physics

at the Institute of Physics.

The position is part of the new Cluster of Excellence PRISMA "Precision Physics, Fundamental Interactions and Structure of Matter", which focuses on key questions concerning the fundamental constituents of matter and their implications for the physics of the Universe. It consists of experimental and theoretical research groups working together in the areas of astro-particle, high energy and hadron physics, nuclear chemistry, as well as precision physics with ultra-cold neutrons and ion traps.

We seek an internationally visible scientist who will significantly extend research activities in the area of theoretical high energy physics at the University of Mainz in association with the PRISMA Cluster of Excellence. The successful candidate is expected to have made significant contributions to the field of theoretical particle physics, in particular in areas such as collider physics, physics beyond the standard model, or model building. A close collaboration with existing experimental groups in PRISMA is expected.

Applicants are expected to have a Ph.D. in physics, a proven first rate research record and to possess the required pedagogical skills for teaching the general subject area „Theoretical Physics" at undergraduate and graduate level. Undergraduate courses are usually given in German. JGU promotes a concept of intensive tutoring and expects a high rate of presence at the university. The appointment requires participation in teaching activities and in the duties of academic administration.

JGU aims at increasing the percentage of women in academic positions and strongly encourages female candidates to apply.

JGU is an equal opportunity employer and particularly welcomes applications from persons with disabilities.

Qualified candidates are asked to submit their applications **by March 1, 2013**, including the usual documents (CV; list of publications; copies of up to three key publications; research proposal) as a single PDF file via the portal **http://www.phmi.uni-mainz.de/stellen**. Applications should be addressed to **"Dekan des Fachbereichs 08, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz"**.

PRiSMA

Cluster of Excellence

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

The Faculty of Physics, Mathematics, and Computer Science at the Johannes Gutenberg University of Mainz (JGU) and the PRISMA Cluster of Excellence invite applications for an appointment at the level of

University Professor (W2 with tenure) in Experimental Astroparticle Physics and Cosmology

at the Institute of Physics.

The position is part of the new Cluster of Excellence PRISMA "Precision Physics, Fundamental Interactions and Structure of Matter", which focuses on key questions concerning the fundamental constituents of matter and their implications for the physics of the Universe. It consists of experimental and theoretical research groups working together in the areas of astro-particle, high energy and hadron physics, nuclear chemistry, as well as precision physics with ultra-cold neutrons and ion traps.

Current research in experimental astroparticle physics at JGU Mainz comprises direct and indirect searches for dark matter with the world-leading experiments XENON and IceCube, as well as neutrino searches for supernovae in the Local Group. We seek an imaginative and internationally visible scientist to further strengthen astroparticle physics research at Mainz and to possibly contribute to an expansion into adjacent areas of cosmology. The successful candidate seeks to establish strong connections with existing PRISMA groups, e.g., in areas of hardware development, data analysis, or experimental particle physics.

Applicants are expected to have a Ph.D. in physics, a proven first rate research record and to possess the required pedagogical skills for teaching. Undergraduate courses are usually given in German. JGU promotes a concept of intensive tutoring and expects a high rate of presence at the university. The appointment requires participation in teaching activities and in the duties of academic administration.

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JGU is an equal opportunity employer and particularly welcomes applications from persons with disabilities.

Qualified candidates are asked to submit their applications **by March 1, 2013**, including the usual documents (CV; list of publications; copies of up to three key publications; research proposal) as a single PDF file via the portal **http://www.phmi.uni-mainz.de/stellen**. Applications should be addressed to **"Dekan des Fachbereichs 08, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz"**.

ALPHA

Two Postdoctoral Positions
The ALPHA Antihydrogen Experiment at CERN
Laser Spectroscopy of Trapped Antihydrogen

The ALPHA experiment at CERN has two immediate (March, 2013) openings for postdoctoral candidates.

These positions, financed by an Advanced Grant from the European Research Council, are initially for two years and renewable for up to five. The focus of the research program will be to develop the laser systems (243 nm) necessary for conducting spectroscopy on trapped antihydrogen atoms. Candidates must have a recent (within the last five years) PhD in physics. Preference will be given to outstanding candidates having experience involving laser interactions with trapped atoms or ions. Knowledge of crygenic and UHV systems is also highly desirable. The successful candidates will be expected to participate in all aspects of the colabortion's experimental program at the Antiproton Decelerator at CERN. This includes commissioning of the new ALPHA-2 antihydrogen trap and involves rotating shift work, as the experiment is manned around the clock. We seek dedicated, self-motivated indiviuals who wish to make an immediate impact on a highly visible experiment. Formal employment will be with the Department of Physics and Astronomy, Aarhus University.

Interested candidates should send their CV and a brief statement of their qualifications and research interests to Professor Jeffrey Hangst, Spokesperson, the ALPHA Collaboration at CERN: jef-frey.hangst@cern.ch. Please include the names and contact email addresses for three references, but do not ask for letters of reference to be sent at this time. The deadline for applications is March 31st, 2013.

AARHUS UNIVERSITY

PRiSMA

Cluster of Excellence

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

The Faculty of Physics, Mathematics, and Computer Science at the Johannes Gutenberg University of Mainz (JGU) and the PRISMA Cluster of Excellence invite applications for an appointment at the level of

Full Professor (W3 with tenure) in Experimental Hadron and Particle Physics

at the Institute of Nuclear Physics.

The position is part of the new Cluster of Excellence PRISMA "Precision Physics, Fundamental Interactions and Structure of Matter", which focuses on key questions concerning the fundamental constituents of matter and their implications for the physics of the Universe. It consists of experimental and theoretical research groups working together in the areas of astro-particle, high energy and hadron physics, nuclear chemistry, as well as precision physics with ultra-cold neutrons and ion traps.

We seek an internationally renowned scientist who has made significant contributions to the field of precision physics and tests of fundamental interactions and who wants to extend research activities in this field at the University of Mainz.

The successful candidate is expected to play a central role within the PRISMA Cluster of Excellence, and in particular for the design and the realisation of experiments at the superconducting accelerator MESA presently under construction, which will be the basis for several precision tests of fundamental interactions. Examples for such experiments include precision measurements of the electroweak mixing angle at low energies and the search for hypothetical particles of the dark sector.

Applicants are expected to have a Ph.D. in physics, a proven first rate research record and to possess the required pedagogical skills for teaching. JGU promotes a concept of intensive tutoring and expects a high rate of presence at the university. The appointment requires participation in teaching activities and in the duties of academic administration.

JGU aims at increasing the percentage of women in academic positions and strongly encourages female candidates to apply.

JGU is an equal opportunity employer and particularly welcomes applications from persons with disabilities.

Qualified candidates are asked to submit their applications **by March 1, 2013**, including the usual documents (CV; list of publications; copies of up to three key publications; research proposal) as a single PDF file via the portal **http://www.phmi.uni-mainz.de/stellen**. Applications should be addressed to **"Dekan des Fachbereichs 08, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz"**.

PRiSMA

Cluster of Excellence

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

The Faculty of Physics, Mathematics, and Computer Science at the Johannes Gutenberg University of Mainz (JGU) and the PRISMA Cluster of Excellence invite applications for an appointment at the level of

Full Professor (W3 with tenure) for Precision Physics with ultra-cold Neutrons

at the Institute of Physics.

The position is part of the new Cluster of Excellence PRISMA "Precision Physics, Fundamental Interactions and Structure of Matter", which focuses on key questions concerning the fundamental constituents of matter and their implications for the physics of the Universe. It consists of experimental and theoretical research groups working together in the areas of astro-particle, high energy and hadron physics, nuclear chemistry, as well as precision physics with ultra-cold neutrons and ion traps.

We seek an internationally renowned researcher, who will extend the current activities in the area of precision physics with ultra-cold neutrons at the University of Mainz as part of the PRISMA Cluster of Excellence. The successful candidate is expected to perform precision experiments for testing fundamental interactions and symmetries at the TRIGA research reactor with its intense source of ultra-cold neutrons. He or she is also expected to collaborate with members of the QUANTUM group on quantum, atomic, molecular, and optical physics, and neutron physics.

Applicants are expected to have a Ph.D. in physics, a proven first rate research record and to possess the required pedagogical skills for teaching. Undergraduate courses are usually given in German. JGU promotes a concept of intensive tutoring and expects a high rate of presence at the university. The appointment requires participation in teaching activities and in the duties of academic administration.

JGU aims at increasing the percentage of women in academic positions and strongly encourages female candidates to apply.

JGU is an equal opportunity employer and particularly welcomes applications from persons with disabilities.

Qualified candidates are asked to submit their applications **by March 1, 2013**, including the usual documents (CV; list of publications; copies of up to three key publications; research proposal) as a single PDF file via the portal **http://www.phmi.uni-mainz.de/stellen**. Applications should be addressed to **"Dekan des Fachbereichs 08, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz"**.

THE UNIVERSITY WISCONSIN MADISON

Director – Wisconsin IceCube Particle Astrophysics Center

The University of Wisconsin-Madison is seeking candidates to provide overall direction and management of the Wisconsin IceCube Particle Astrophysics Center (WIPAC). UW-Madison is responsible to the National Science Foundation and the IceCube Collaboration for the maintenance and operations of the IceCube Neutrino Observatory, a kilometer-scale neutrino detector at the South Pole. The collaboration includes scientists from over thirty research institutions worldwide who collectively participate in studies of high-energy neutrinos from cosmic sources and a range of scientific topics in Astroparticle Physics.

The Director of WIPAC is expected to provide vision and leadership for a research environment that accommodates a diverse range of activities involving world-class research in the physical sciences; overall scientific leadership, strategic planning, and management of finances and growth; maintain a scientific climate that fosters creativity, collaboration and productivity in research; and manage external relations within the UW-Madison campus as well as in the wider scientific community to facilitate support and collaboration for its educational and research activities. The Director will initiate, establish, develop and manage collaborative relationships with the University's scientific community, state and federal agencies, and other private and public sectors.

The Director of WIPAC will also serve as the Director of Operations for the IceCube Neutrino Observatory.

A Ph.D. in particle physics, astrophysics or a related scientific field is required.

Qualified candidates will have at least ten years of experience in a senior scientific leadership role with participation in the management of a large-scale international project. The ideal candidate has an international reputation and may be a tenured/tenured-track faculty, or could be qualified as tenurable in the Physical Sciences. Starting pay is USD $100,000 annual plus excellent benefits.

To view the full Position Vacancy Listing (PVL) and position description, go to **http://www.ohr.wisc.edu/pvl/pv_075086.html**

To apply, send your cover letter describing your vision for WIPAC and the position of Director, a CV, and three professional letters of recommendation to **Dean M. Cadwallader, Dean of the Graduate School and Vice Chancellor for Research, c/o Kristine Leonowicz,** via email to **leonowicz@grad.wisc.edu**

PRISMA Cluster of Excellence

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

The Faculty of Physics, Mathematics, and Computer Science at the Johannes Gutenberg University of Mainz (JGU) and the PRISMA Cluster of Excellence invite applications for an appointment at the level of

University Professor (W2 with tenure) in Lattice Gauge Theory

at the Institute of Nuclear Physics.

The position is part of the new Cluster of Excellence PRISMA "Precision Physics, Fundamental Interactions and Structure of Matter", which focuses on key questions concerning the fundamental constituents of matter and their implications for the physics of the Universe. It consists of experimental and theoretical research groups working together in the areas of astro-particle, high energy and hadron physics, nuclear chemistry, as well as precision physics with ultra-cold neutrons and ion traps.

We seek an imaginative and internationally visible scientist who will significantly extend research activities in the area of lattice gauge theory at the University of Mainz in association with the PRISMA Cluster of Excellence.

The successful candidate is expected to have made significant contributions to the field of lattice gauge theory, in particular in areas such as spectroscopy and structure of hadrons, hadronic matrix elements or investigations of the QCD phase diagram. Candidates are expected to possess the required pedagogical skills for teaching the general subject area of "Theoretical Physics" at undergraduate and graduate level. Undergraduate courses are usually given in German.

Applicants are expected to have a Ph.D. in physics, a proven first rate research record and to possess the required pedagogical skills for teaching. Undergraduate courses are usually given in German. JGU promotes a concept of intensive tutoring and expects a high rate of presence at the university. The appointment requires participation in teaching activities and in the duties of academic administration.

JGU aims at increasing the percentage of women in academic positions and strongly encourages female candidates to apply.

JGU is an equal opportunity employer and particularly welcomes applications from persons with disabilities.

Qualified candidates are asked to submit their applications **by March 1, 2013**, including the usual documents (CV; list of publications; copies of up to three key publications; research proposal) as a single PDF file via the portal **http://www.phmi.uni-mainz.de/stellen**. Applications should be addressed to **"Dekan des Fachbereichs 08, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz".**

PRISMA Cluster of Excellence

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

The Faculty of Physics, Mathematics, and Computer Science at the Johannes Gutenberg University of Mainz (JGU) and the PRISMA Cluster of Excellence invite applications for an appointment at the level of

University Professor (W2, tenure track) in Experimental Particle Physics with emphasis on Flavour Physics

at the Institute of Physics.

The position is part of the new Cluster of Excellence PRISMA "Precision Physics, Fundamental Interactions and Structure of Matter", which focuses on key questions concerning the fundamental constituents of matter and their implications for the physics of the Universe. It consists of experimental and theoretical research groups working together in the areas of astro-particle, high energy and hadron physics, nuclear chemistry, as well as precision physics with ultra-cold neutrons and ion traps.

We seek an imaginative and internationally visible researcher who is willing to strengthen and extend on-going research in neutrino physics or quark flavour physics. The research will be performed in the framework of the PRISMA Cluster of Excellence. The studies should concentrate on tests of the Standard Model and on probing proposed extensions by performing precision measurements of particle properties, by studying the particle mixing patterns or by searching for rare decays.

Applicants are expected to have a Ph.D. in physics, a proven first rate research record and to possess the required pedagogical skills for teaching. Undergraduate courses are usually given in German. JGU promotes a concept of intensive tutoring and expects a high rate of presence at the university. The appointment requires participation in teaching activities and in the duties of academic administration.

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CAREER VIDEOS

The application of physicists within a global engineering business

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- *"Submarines business overview"* and *"Civil nuclear business overview"* with Steve Lawler

Presented by Rolls-Royce

Visit **brightrecruits.com/videos**

LANCASTER UNIVERSITY DEPARTMENT OF PHYSICS

Chair/Reader in Experimental Neutrino Physics

Reference: A649 Professorial (minimum £59,669)/ Reader £47,314 - £53,233

Lecturer in Experimental Neutrino Physics

Reference: A650 £32,267 - £36,298

We wish to appoint two outstanding experimental particle physicists at the level of Chair/Reader (equivalent to a Full Professor/Associate Professor respectively) and Lecturer (equivalent to an Assistant Professor) to lead/support an expansion of our experimental neutrino physics programme at current and future long baseline facilities.

You will be expected to develop a world-class research activity in this field and will be able to join an existing group working with the T2K collaboration at JPARC (one professor, one lecturer, two researchers and several PhD students) as well as build up a Lancaster contribution to one of the future long baseline neutrino oscillation projects.

Our department was ranked first and equal-first respectively in the 2008 and 2001 UK Research Assessment Exercises (RAE) and is seeking to further enhance its scientific standing.

The posts are permanent and tenable from 1 October 2013. In addition to your research activities, you will also be involved with undergraduate and postgraduate teaching.

Please contact Professor Peter Ratoff (Head of Department) if you wish to have an informal discussion about this opportunity: Email: p.ratoff@lancaster.ac.uk Tel: +44 1524 593639.

We are strongly committed to fostering diversity within our community as a source of excellence, cultural enrichment, and social strength. We welcome those who would contribute to the further diversification of our department.

Closing date: 21 March.

www.lancaster.ac.uk/jobs

New position at Bergoz Instrumentation for an accelerator physicist or engineer

BUSINESS MANAGER

in charge of CSS Customer Support and Sales to mature markets and market development in CIS and India. This new position has an excellent growth potential. Mature markets are Europe, U.S.A.-Canada, Japan, China, Korea and Taiwan. Our distributors -- GMW for North America and Repic K.K. for Japan are competent and reliable. All other countries are served directly from our main office in France (3 km. from Geneva Switzerland and CERN).

Our Business Manager will be chosen on the basis of personality, languages, international culture and knowledge of accelerators. This position requires lots of traveling, long hours of work and a relentless willingness to learn and progress. Our company will deploy all efforts for the success of its new Business Manager. He/she can rely on six top professionals in accelerator physics and instrumentation, trade and finance for assistance. Our highly qualified manufacturing staff assures highest quality standards. Attractive compensation.
Open to all nationalities.

Send your application with relevant documentation to
Julien Bergoz,
Espace Allondon Ouest,
01630 Saint Genis Pouilly,
France.

bergoz Instrumentation

The Cockcroft Institute of Accelerator Science and Technology

LANCASTER UNIVERSITY DEPARTMENT OF PHYSICS

Chair in Accelerator Physics and Associate Director of the Cockcroft Institute

Reference: A589 – Professorial (minimum £59,078)

The Cockcroft Institute, a unique collaboration between the Universities of Lancaster, Manchester, Liverpool, the Science and Technology Facilities Council and industry brings together the best accelerator scientists, engineers, educators and industrialists to conceive, design, construct and use innovative instruments of discovery and to lead the UKs participation in flagship international experiments. The Institute has been involved in the development of the UKs first Free Electron Laser (FEL) on the ALICE accelerator test facility and is contributing towards development of an advanced FEL test facility (CLARA) to advance worldwide FEL reserach. It has a strong collaboration with CERN in the areas of LHC and its various upgrades, anti-matter research and future developments in high energy accelerators, and with the ESS at Lund. The Institute has the singular distinction of opereating from its purpose built office and laboratory infrastructure adjacent to the Daresbury Laboratory, one of the two major national accelerator laboratories in the UK.

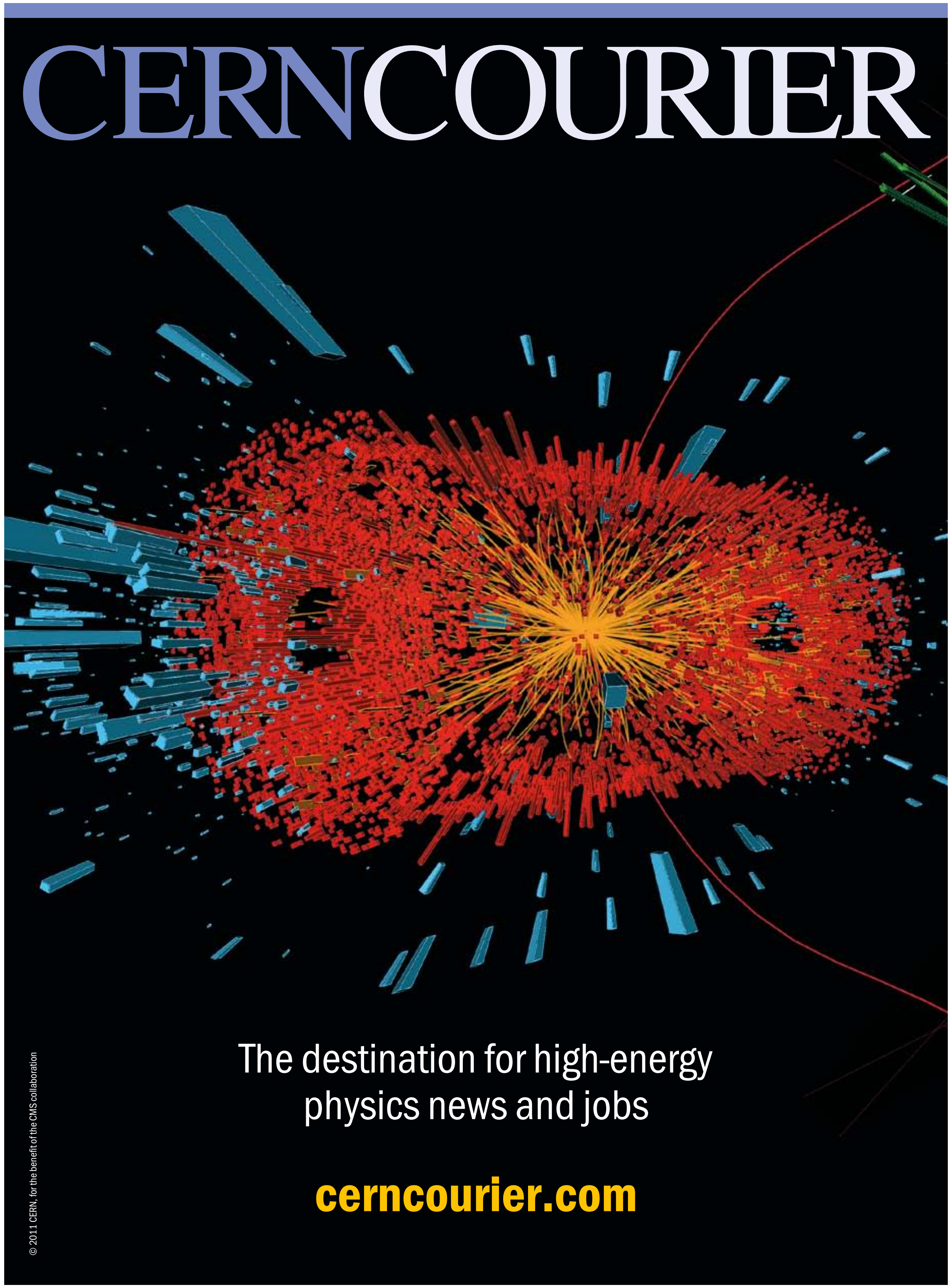
As a founding member of the Cockcroft Institute and with the UK's highest ranking physics department in the 2008 Research Assessment Exercise, Lancaster University is seeking to appoint a Chair (Full Professor) in Accelerator Physics who will hold a significant leadership position, Associate Director of the Cockcroft Institute from Lancaster University, to further consolidate the Institute's international profile. The incumbent will be a member of the Cockcroft Institute Executive Management Committee and will be expected to advance theoretical and/or experimental research in accelerator physics in close collaboration with Institute members in the Physics & Engineering Departments, other universities, and Daresbury and Rutherford Appleton Laboratories.

You must have a Ph.D. in accelerator physics, particle physics, electrical engineering or a related discipline, with an outstanding research and publications record and a high level appreciation and grasp of potential future international accelerator developments.

Informal inquiries about the institute may be made to Professor Swapan Chattopadhyay, swapan@cockcroft.ac.uk For information about the Lancaster University Physics Department: Professor Peter Ratoff, p.ratoff@lancaster.ac.uk Salary is expected to be on Band 1 of the professorial scale.

Closing Date: 28 February 2013.

www.lancaster.ac.uk/jobs



Bookshelf

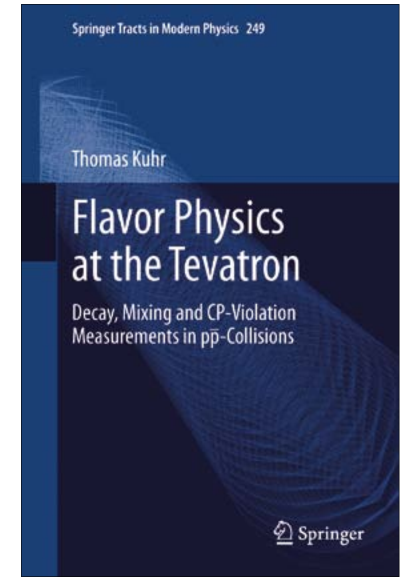
Flavor Physics at the Tevatron: Decay, Mixing and CP Violation Measurements in $p\bar{p}$ Collisions
By Thomas Kuhr
Springer
Hardback: £117 €137.10
Paperback: £109 €119.19

The Tevatron collider operated by Fermilab close to Chicago was – until the LHC at CERN took over – the most powerful particle accelerator on Earth, colliding protons and antiprotons with, finally, a centre-of-mass energy of almost 2 TeV. Among many interesting results, the key discovery was the observation of the top quark by the CDF and DØ collaborations in 1995. In $p\bar{p}$ collisions, huge numbers of B and D mesons are also produced, offering sensitive probes for testing the quark-flavour sector of the Standard Model, which is described by the Cabibbo-Kobayashi-Maskawa (CKM) matrix. A closely related topic concerns violation of the charge-parity (CP) symmetry, which can be accommodated through a complex phase in the CKM matrix. Physics beyond the Standard Model may leave footprints in the corresponding observables.

In this branch of particle physics, the key aspect addressed at the upgraded Tevatron (Run-II) was the physics potential of the B^0_s mesons, which consist of an anti-bottom quark and a strange quark. Since these mesons and their antiparticles were not produced in the e^+e^- B factories that operated at the $\Upsilon(4S)$ resonance, they fall in the domain of B-physics experiments at hadron colliders, although the Belle experiment could get some access to these particles with the KEK B-factory running at the $\Upsilon(5S)$ resonance. Since the Tevatron stopped operation in autumn 2011, the experimental exploration of the B^0_s system has been fully conducted at the LHC, with its B-decay experiment LHCb.

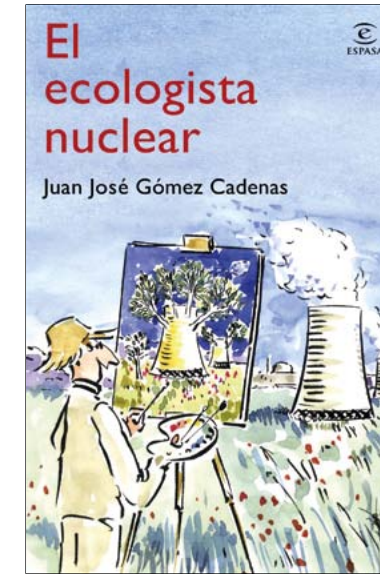
The CDF and DØ collaborations did pioneering work in B physics, which culminated in the observation of B^0_s–$\bar{B}^0_s$ mixing in 2006, first analyses of CP-violating observables provided by the decay $B^0_s \to J\psi\phi$ around 2008, and intriguing measurements of the dimuon charge asymmetry by DØ in 2010, which probes CP violation in B^0_s–$\bar{B}^0_s$ oscillations.

The author of this book has been a member of the CDF collaboration for many years and gives the reader a guided tour through the flavour-physics landscape at the Tevatron. It starts with historical remarks and then focuses on the quark-flavour sector



of the Standard Model with the CKM matrix and the theoretical description of mixing and CP violation, before discussing the Tevatron collider, its detectors and experimental techniques. After these introductory chapters, the author brings the reader in touch with key results, starting with measurements of lifetimes and branching ratios of weak b-hadron decays and their theoretical treatment, followed by a discussion of flavour oscillations, where B^0_s–$\bar{B}^0_s$ mixing is the highlight. An important part of the book deals with various manifestations of CP violation and the corresponding probes offered by the B^0_s system, where $B^0_s \to J\psi\phi$ and the dimuon charge-asymmetry are the main actors. Last, rare decays are discussed, putting the spotlight on the $B^0_s \to \mu^+\mu^-$ channel, one of the rarest decay processes that nature has to offer. While the book has a strong focus on the B^0_s system, it also addresses Λ_b decays and charm physics.

This well written book with its 161 pages is enjoyable to read and offers a fairly compact way to get an overview of the B-physics programme conducted at the Tevatron in the past decade. A reader familiar with basic concepts of particle physics should be able to deal easily with the content. It appears suited to experimental PhD students making first contact with this topic, but experienced researchers from other branches of high-energy physics may also find the book interesting and useful.



Topics such as the rare decay $B^0_s \to \mu^+\mu^-$, which has recently appeared as a first 3.5σ signal in the data from LHCb, and measurements of CP violation in B^0_s decays will continue to be hot topics in the LHC physics programme during this decade, complementing the direct searches for new particles at the ATLAS and CMS detectors.

● *Robert Fleischer, Nikhef and Vrije Universiteit Amsterdam.*

El ecologista nuclear
By Juan José Gómez Cadenas
Espasa Calpe
Paperback: €22.95
Also published as:
L'ambientalista nucleare
Springer
Paperback: €25
E-book: €22.99
The Nuclear Environmentalist
Springer
Paperback: £24.99 €29.07
E-book: £25.99 €26.99

Juan José Gómez Cadenas is the director of the Neutrino Physics Group at Valencia University but is best known by the general public as a novelist – in 2008 he wrote *Materia Extraña*, a scientific thriller (p23) – and as an expert in science popularization. Even in a purely scientific environment he is able to deliver information in a most enjoyable way, as I found when I attended a scientific talk that he gave at CERN.

This same ease in communicating is

Bookshelf

recognizable in *El ecologista nuclear*, his book about the topic of renewable and green energy and the role of the nuclear energy. I read the Italian edition of the book and although I noticed that the translation was not always perfect and, especially in some cases, that it did not improve the quality of the reading, I really enjoyed the book and its factual approach to this delicate and controversial topic.

Gómez Cadenas makes his point of view clear in the first chapter: "All that glitters is not green." This could shock the uninitiated because it immediately leads the reader to face "the problem": climate change is a "bomb (that) has been activated" and humankind is "playing with fire". The author does not just present this scenario as an opinion. Rather, he justifies all of his statements with graphs, scientific data and evidence.

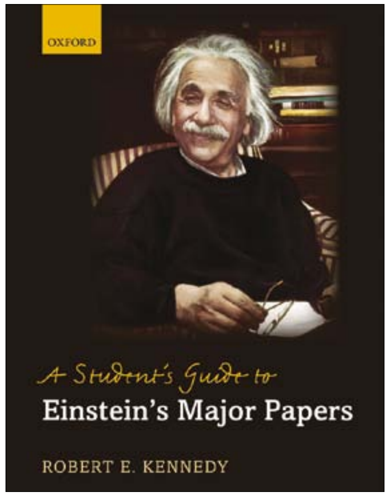
The chapters that follow are a journey through the various solutions to the problem, in which he makes a strong case for the use of nuclear energy. Using data and graphs, he successfully proves that "safe" nuclear power is the only viable solution. I emphasize the word "safe" because this is the delicate point that matters most to the general public. Unlike other authors, instead of avoiding talking about the problem of safety, Gómez Cadenas discusses it openly, with constant reference to scientific data.

I like the book; I like the author's open and honest approach, his competence and his rigorous summaries of a global problem that concern us all. I would recommend reading it before voting for any topic related to the energy problem on our planet.

● *Antonella Del Rosso, CERN.*

A Student's Guide to Einstein's Major Papers

By Robert E Kennedy
Oxford University Press
Hardback: £25



"There is probably no physicist living today whose name has become so widely known as that of Albert Einstein." This is the opening sentence of Svante August Arrhenius, chair of the Nobel Committee, on occasion of the award of the 1921 Nobel Prize in Physics on 10 December 1922. "Most discussion centres on his theory of relativity," he follows and I agree. Ninety years later we measure Einstein in terms of how he spearheaded the transformation of our understanding of space, time and the universe as a whole. His contributions to all other fields of knowledge, though extremely impressive and Nobel prize winning, is similar to work of the other Nobel laureates in physics. Even so, you will not learn in this book that Einstein won the prize "for his services to theoretical physics, and especially for his discovery of the law of the photoelectric effect", discussed in chapter 2. Maybe a student does not deserve to be distracted by such a petty fact, but the volume literally overflows with extraneous historical facts.

Relativity – in its multiple reincarnations – is the work of a genius, taking an approach outside his contemporary world; so far out, indeed, that no common ground could be found for its immediate recognition. In my opinion, a present-day guide to the work of Einstein can have only one purpose and that is to show Einstein's path to relativity, both special and general. In this book, I do not see a clear position on what it is that Einstein achieved in his relativity papers that we today regard as everlasting. The big scientific ideas that Einstein introduced are, effectively, missing.

This observation is easily proved by example. The unprecedented and universally recognized contribution that Einstein made in developing his path to special relativity was to give each material object its own clock, so as to undo the idea of a universal time. Today, physicists use "proper" time, the terminology introduced by Hermann Minkowski in 1908. It was the attribution of proper time to each material body that was the paradigm-shifting idea. This "guide" does not have proper time in the index and I did not see it written down in the book. However, I did see "local time", e.g. in a quote on page 111 from Lorentz's book and a few more times after that. Why is there no connection to the concept of proper time? Even more perplexing, the related concept of time dilation is missing. The words "time dilation" appear in the book exactly once, definitely by accident. Any student will want to know what Einstein had to say about that, after all, the twin paradox is interesting to most students.

The evolution of Einstein's views on aether is another topic on which a student reading Kennedy's treatise cannot achieve clarity. Aether figures many times in the book and its index, yet the student seeking to understand how Einstein viewed it will not find an answer (although page 21 clearly states Lorentz's 1905 view of aether). Einstein created the needed clarity in 1920: "We may say that according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an aether. According to the general theory of relativity, space without aether is unthinkable; for in such space there would not only be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space–time intervals in the physical sense. But this aether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of parts which may be tracked through time. The idea of motion may not be applied to it." (*From Ether and the Theory of Relativity* (1920), available in *Sidelights on Relativity* (Dover)).

In summary, Kennedy's book is not an easy read and misses out on discussion of key conceptual ideas present in Einstein's major papers.

● *Johann Rafelski, University of Arizona.*

Book received

Foundations of Space and Time: Reflections on Quantum Gravity

By Jeff Murugan, Amanda Weltman and George F R Ellis (eds.)
Cambridge University Press
Hardback: £45 $70
Paperback: $56

After almost a century, the field of quantum gravity remains as difficult and inspiring as ever. Today, it finds itself a field divided, with two major contenders dominating: string theory and loop quantum gravity. However, a number of other innovative schemes are providing promising new avenues. Encapsulating the latest debates, this book details the different approaches to understanding the nature of space and time. It brings together leading researchers to explore in a comprehensive coverage all of the current approaches to solving the problem of quantum gravity, addressing the strengths and weaknesses of each approach, to give researchers and graduate students an up-to-date view of the field.

Viewpoint

The incomprehensibility principle

Gordon Fraser, long-time editor of *CERN Courier*, ponders on paying attention.

Gordon in 2002.

Educators and psychologists invented the term "attention span" to describe the length of time anyone can concentrate on a particular task before becoming distracted. It is a useful term but span, or duration, is only one aspect of attention. Attention must also have an intensity – and the two variables are independent of each other. Perhaps one can postulate an analogue of the Heisenberg uncertainty principle, in which the intensity of attention multiplied by its span cannot exceed some fixed value. I call this the "incomprehensibility principle" and I have had plenty of opportunities to observe its consequences.

In the hands of skilled presenters, information can be carefully packaged as entertainment so that the attention needed to digest it is minimal. The trick is to mask the effort with compelling emotional appeal and a floppy boy-band haircut. However, the need to pay attention is still there; in fact, absorbing even the most trivial information demands a modicum of attention. How many of us, when leaving a cinema, have had the nagging feeling that although the film made great entertainment some details of the plot remained less than crystal clear?

The existence of a minimum level of attention suggests that it is, in some sense, a quantum substance. This means that under close examination, any apparently continuous or sustained effort at paying attention will be revealed as a series of discrete micro-efforts. However, while attention can be chopped up and interleaved with other activities, even tiny pulses of attention demand full concentration, to the exclusion of all other voluntary activities. Any attempt at multitasking, such as using a mobile phone while driving a car, is counterproductive.

The incomprehensibility principle plays a major role in education, where it is closely linked to the learning process. Because of the subject matter and/or the teacher, some school lessons require more time to assimilate than others. This trend accelerates in higher education. In my case, a hint of what was to come appeared during my third year of undergraduate physics, when I attended additional lectures on quantum mechanics in the mathematics department at Imperial College London.

My teacher was Abdus Salam, who went on to share the Nobel Prize for Physics in 1979. Salam's lectures were exquisitely incomprehensible; as I look back, I realize he was probably echoing his own experiences at Cambridge some 15 years earlier at the hands of Paul Dirac. But he quickly referred us to Dirac's book, *The Principles of Quantum Mechanics*. At a first and even a second glance, this book shone no light at all but after intense study, a rewarding glimmer of illumination appeared out of the darkness.

Motivated by Salam's unintelligibility, I began postgraduate studies in physics only to find that my previous exposure to incomprehensibility had been merely an introduction. By then, there were no longer any textbooks to fall back on and journal papers were impressively baffling. With time, though, I realized that – like Dirac's book – they could be painfully decrypted at "leisure", line by line, with help from enlightened colleagues.

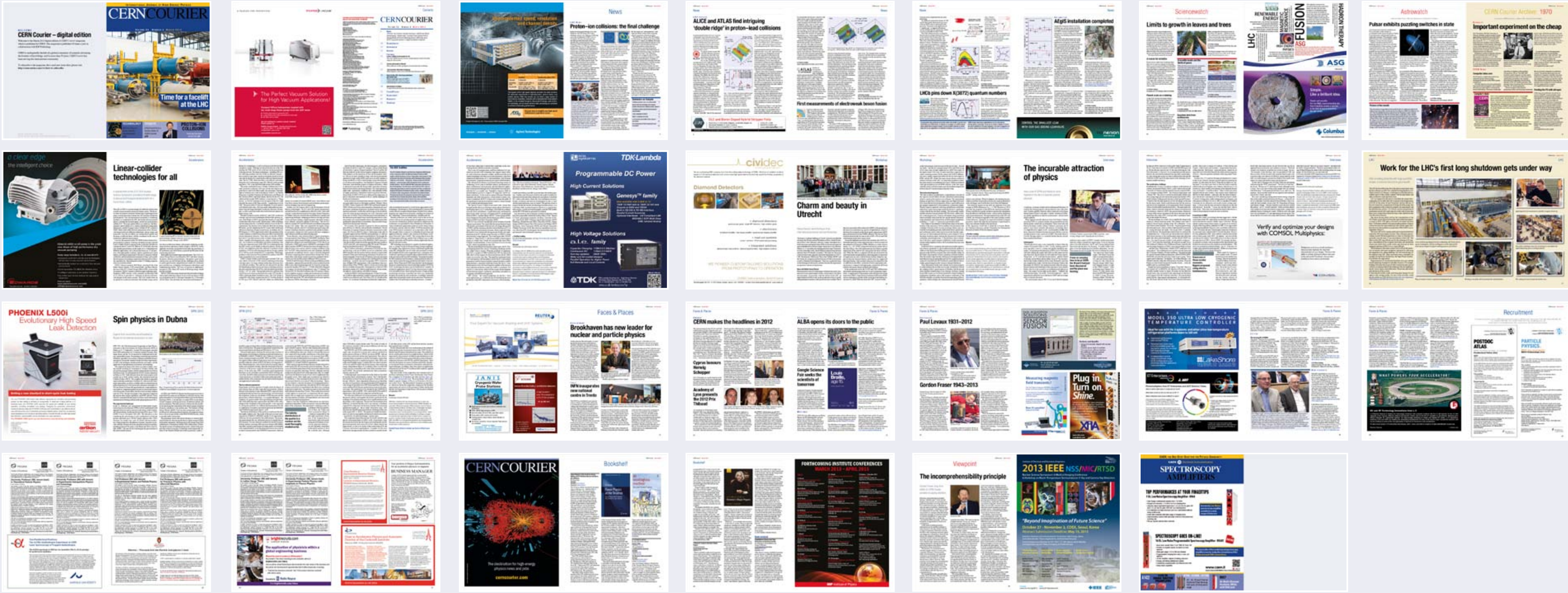
The real problem with the incomprehensibility principle came when I had to absorb information in real time, during seminars and talks. The most impenetrable of these talks always came from American speakers because they were, at the time, wielding the heavy cutting tools at the face of physics research. Consequently, I developed an association between incomprehensibility and accent. This reached a climax when I visited the US, where I always had the feeling that dubious characters hanging out at bus stations and rest stops must somehow be experts in S-matrix theory and the like, travelling from one seminar to the next. Several years later, when I was at CERN, seminars were instead delivered in thick European accents and concepts such as "muon punch-through" became more of an obstacle when pointed out in a heavy German accent.

Nevertheless, I persevered and slowly developed new skills. The incomprehensibility principle cannot be bypassed but even taking into account added difficulties such as the speaker's accent or speed of delivery – not to mention bad acoustics or poor visual "aids" – it is still possible to optimize one's absorption of information.

One way of doing this is to monitor difficult presentations in "background mode", paying just enough attention to follow the gist of the argument until a key point is about to be reached. At that moment, a concerted effort can be made to grab a vital piece of information as it whistles past, before it disappears into the obscurity of the intellectual stratosphere. The trick is to do this at just the right time, so that each concentrated effort is not fruitless. "Only cross your bridges when you come to them", as the old adage goes.

By adopting this technique, I was able to cover frontier meetings on subjects of which I was supremely ignorant, including microprocessors, cosmology and medical imaging, among others. Journalists who find themselves baffled at scientific press conferences would do well to follow my example, for the truth is that there will always be a fresh supply of incomprehensibility in physics. Don't be disappointed!

● *Gordon Fraser. Gordon, who was editor of* CERN Courier *for many years, wrote this as a 'Lateral Thought' for* Physics World *magazine but died before the article could be revised (see obituary p36). It was completed by staff at* Physics World *and is published in both magazines this month as a tribute.*



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